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## MESEMBRIOXYLON TIRUMANGALENSE, A NEW SPECIES FROM THE SRIPERMATUR GROUP NEAR MADRAS

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### INTRODUCTION

THE present paper deals with a new species of *Mesembrioxylon* from the Sripermatgur group, named after the town, Sripermatgur, which lies 25 miles W.S.W. of Madras. The specimen was collected by me (April, 1952) from Tirumangalam, near Sripermatgur. The exact locality where it occurs *in situ* is not known.

The various geological formations in India from where the genus *Mesembrioxylon* has been reported are the 'Tiki beds' of the Maleri stage in South Rewah, the Gollapili group in Godavari District, the Sripermatgur group and lastly the Tertiary beds at Tiruvakkarai near Pondicherry. All these beds belong to the upper Gondwanas except the Tiruvakkarai grits. Three fossil woods were reported by Bruce Foote (1873) from the vicinity of Sripermatgur. Describing a fossil wood from Vellum, he says (p. 104): "This fossil wood which is firmly imbedded in the grits is beautifully silicified, every pore of the close grained woody structure having been perfectly preserved and the exogenous character being extremely distinct." From the same locality a very handsome piece of silicified wood was reported to have been found long ago on the bottom of an irrigation channel. Sahni (1931) described two species of *Mesembrioxylon* from the Sripermatgur area.

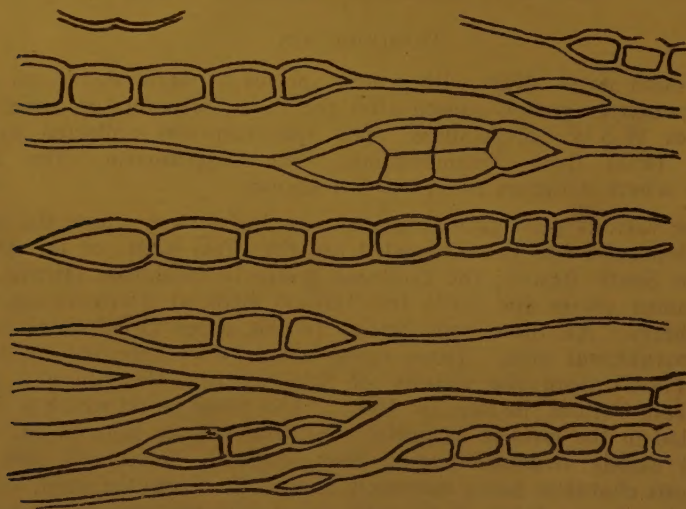
The geology of the area is quite simple, the chief formations being buff, variegated shales and clays resting on gritty sandstones. But the southern part of the area is occupied by a series of grits, sandstones and sandy clays whose exact relation to the shales is not quite clear. These shales contain both marine animal and plant remains of Rajmahal age. Among the invertebrate fossils found here, *Leda* and *Pecten* are common. Two or three ammonites have been recorded from here by Foote (1873). As a whole these fossiliferous shales are covered by the recent lateritic and alluvial formations. These shale beds have been referred to the 'Kota stage' among the upper Gondwana

subdivision (Lower Jurassic) and thought to be the equivalents of the Vaemavaram and Raghavapuram shales along the coastal region.

#### DESCRIPTION

The solitary specimen is a block of ferruginous rock with very fine-grained texture. It consists of only secondary wood and measures about 7 cm. in length and 5 cm. in width. The growth rings are narrow and can be seen even with the naked eye. The curvature of these rings shows that this portion of the wood is not far from the pith. The cells of the spring wood are larger than the cells of the summer wood and are roughly rectangular in shape. The summer wood contains cells with thicker walls (Pl. VII, Fig. 2). The width of the tracheidal cells, measured tangentially, ranges from 120 to 160  $\mu$ . Xylem parenchyma is absent.

In tangential section of the medullary rays, the cells are either isodiametric or slightly higher than broad (Pl. VII, Fig. 3; Text-Fig. 1).

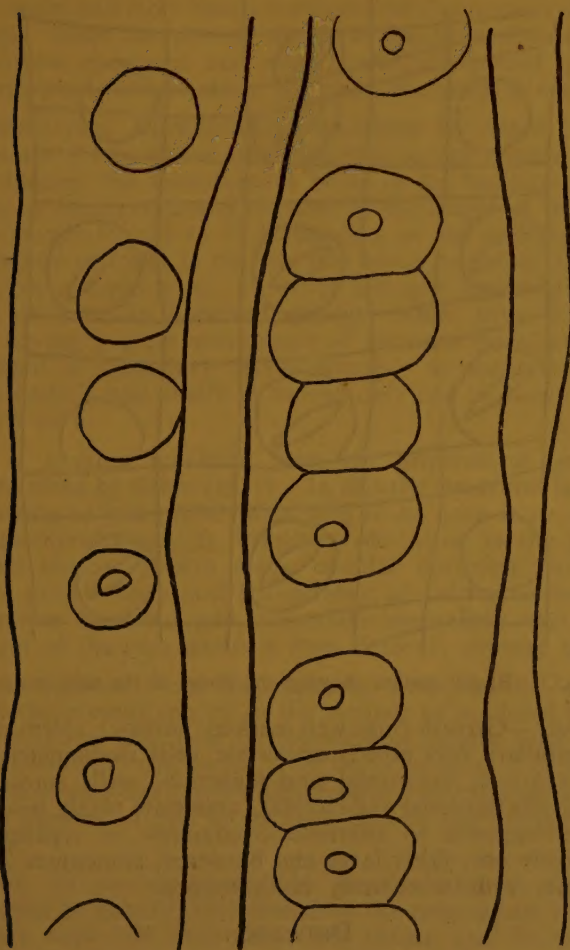


TEXT-FIG. 1. A portion of the tangential section showing the distribution of medullary rays,  $\times 160$ .

The diameter of these cells varies from 26 to 50  $\mu$ . The medullary rays are mostly uniseriate but biseriate ones are also very common. The height of these rays is from 1 to 15 cells and rarely reaches 23, the average being 4. The medullary rays do not show any pitting on the tangential walls.

The radial section shows the bordered pits in the tracheids which are usually circular and uniseriate. When in contact they are slightly flattened above and below. Both contiguous as well as separate pits are found (Pl. VII, Fig. 4; Text-Fig. 2). All of them are almost of the



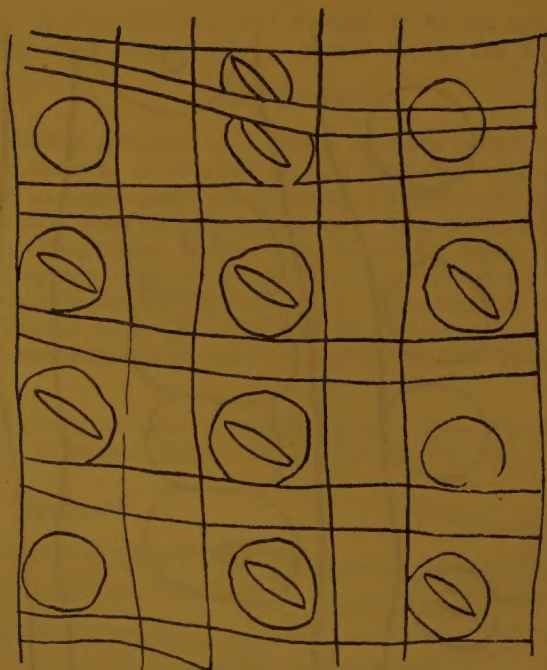


TEXT-FIG. 2. Radial section showing the bordered pits,  $\times 650$ .

same size, the diameter being from  $13\mu$  to  $16\mu$ . Sometimes the bordered pits are not well preserved, and then they appear like a simple pit.

The pits in the field are well preserved (Pl. VII, Fig. 5). They are round or oval in shape and usually 1 to 3 in number, very rarely 4. In most cases a single large pit is seen occupying the field completely (Eiporen) (Pl. VII, Fig. 6; Text-Fig. 3). The pores of the pits are narrow, elongated and placed slightly oblique to the vertical.

As will be shown below, this species will have to be regarded as a new one and I therefore give the diagnosis as follows:



TEXT-FIG. 3. Radial section showing the pores of the field pits,  $\times 650$ .

*Diagnosis.*—Growth rings well marked, narrow; xylem parenchyma absent; medullary rays mostly uniseriate, cells isodiametric or slightly higher than broad, horizontal and tangential walls smooth. Radial pits of tracheids bordered and circular, uniseriate rarely biseriate, when biseriate sub-opposite to alternate, contiguous or separate. Pits in the field mostly one, fairly large and bordered, sometimes 2 to 3 small bordered pits with a narrow, oblique pore.

#### DISCUSSION

The absence of xylem parenchyma, the uniseriate and sub-oppositely arranged biseriate pitting, the uni- and bi-seriate medullary rays and the smaller number of pits in the field, in particular the presence of eiporen with narrow, oblique pores indicate that the wood may belong to the genus *Mesembrioxylon*. At the same time it may also be confused with *Cupressinoxylon*, which also shows somewhat similar characters. There is always the difficulty of distinguishing the *Mesembrioxylon* wood from the *Cupressinoxylon* type and as Sahni (1931, p. 53) says, "Among the numerous species assigned to the latter genus there are not a few that might with equal justice be described under *Podocarpoxylon* or *Mesembrioxylon* (e.g., *Cupressinoxylon Hortu Stopes*)." According to Gothan the only distinctive character of any value is the medullary ray pitting in the spring wood, the pore being narrow and more or less vertical in *Mesembrioxylon* (podocarpoid



pitting) but wider and more nearly horizontal in *Cupressinoxylon* (cupressoid pitting). Since the present wood, as has been described before, shows a narrow elongated and almost vertically placed pore in the medullary ray pit, it can be safely put under the genus *Mesembrioxylon*.

*Mesembrioxylon Parthasarathyi* described by Sahni (1931) from the Sripermatpur group shows more affinities to our present wood than any other species, the resemblances being in the bordered pits which are separate or contiguous and circular, in the height of the medullary rays which ranges from 1 to 18 in number, in the isodiametric nature of the medullary ray cells, in the field pits which are round and bordered with a narrow oblique pore. However the new species differs in the occurrence of biseriate bordered pitting, often with elliptic pits; further in having a great percentage of biseriate medullary rays; in the low height of medullary rays (average 4 as compared with 8 in *M. Parthasarathyi*), and finally in having only one to 3 pits in the field instead of 2 to 6.

There is another specimen from the Sripermatpur group which was also described by Sahni (1931). In this the structural features were not clear owing to bad preservation and so he gave it no other name than *Mesembrioxylon* sp. It resembles our wood in the presence of well marked narrow growth rings, circular bordered pits, either in single or in double rows and the number of field pits, but differs in having opposite bordered pits, uniseriate medullary rays and lastly by the height of the rays which is from 5 to 45, average being 20.

*M. schmiedianum* from Tiruvakkarai, described by Sahni (1931) agrees with the present species in the manner of bordered pitting with circular or elliptical pits, field pitting with an oblique pore in each pit and in the absence of resin canals. On the other hand it is distinguished by the height of medullary rays which is from 2 or 3 to over 100 (average 36), by the number of pits in the field and by the presence of xylem parenchyma.

Likewise, *M. godaverianum* from Bogalpalmila, in the Godavari area, described by Sahni (1931) resembles the new species in the height of medullary rays and their uniseriate nature and in the bordered pitting. The Godavari species is characterised by the absence of growth rings, the large number of pits in the field and the presence of xylem parenchyma full of resin and also by its uniseriate medullary rays.

Lastly there is another species from the Maleri stage, Tiki in Rewah, namely *M. malerianum* (Sahni, 1931). This differs from the present wood by its greater number of pits in the field and in the presence of uniseriate arrangement of medullary rays.

Almost all foreign species differ from the one under consideration in having a very low height of the medullary rays, in the presence of xylem parenchyma, either in abundance or in scattered condition and in the uniseriate bordered pitting.

*M. woburnense*, described by Stopes (1915) from Bedfordshire, agrees to some extent in the height of the medullary rays and in the

bordered pitting, but differs in the presence of xylem parenchyma all through the wood, the presence of rims of Sanio and the single oval pit in the field.

Kubart (1915) described *M. Schwendæ* from upper Austria which shows greater affinities to the present species, but is distinguished by its xylem parenchyma and the uniseriate medullary rays.

Finally mention may be made of the Tasmanian species, *M. Hookeri*, described by Arber (1904). It differs in the uniseriate medullary rays, the presence of rims of Sanio and a large simple, single pit in the field.

From the above it will be seen that the present wood cannot be identified with any of the species of *Mesembrioxylon* so far recorded and it is described here as *M. tirumangalense* sp. nov.

#### ACKNOWLEDGEMENTS

I take this opportunity to thank Professor O. A. Höeg for the constant encouragement and critical suggestions he has given during my work.

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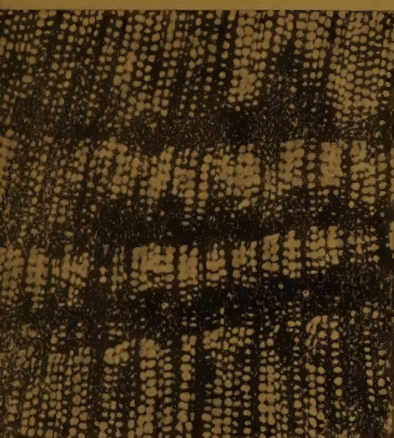
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#### EXPLANATION OF PLATE

##### PLATE VII

- FIG. 1. Transverse section under low power showing the growth rings (*g.r.*),  $\times 50$ .
- FIG. 2. Transverse section showing the spring and summer woods,  $\times 90$ .
- FIG. 3. Tangential section showing the distribution of medullary rays (*m.r.*),  $\times 90$ .
- FIG. 4. Radial section showing the nature of the bordered pits (*b.p.*),  $\times 360$ .
- FIG. 5. Radial section showing the number of pits (*f.p.*) in the field,  $\times 350$ .
- FIG. 6. Another radial section illustrating eiporen (*e.p.*) with oblique pores,  $\times 350$ .





1

*g. r.*

*m. r.*

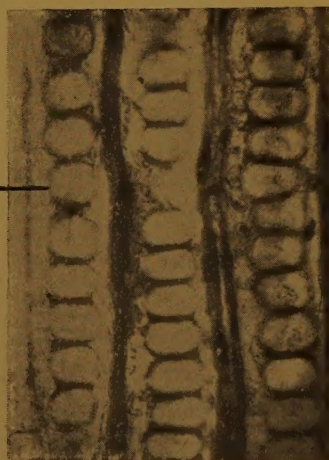


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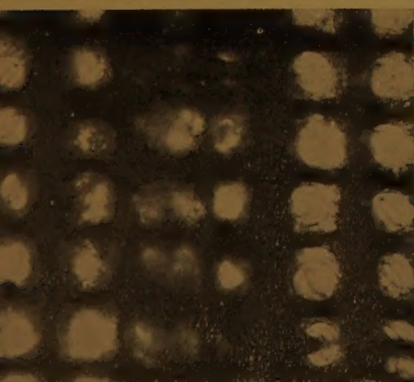


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*b. p.*



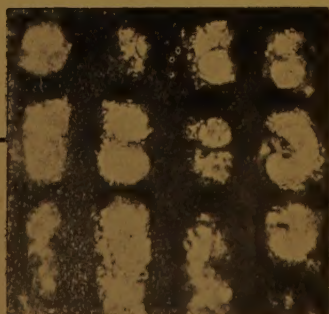
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6

*f. p.*

*e. p.*



5





# EFFECT OF VARYING PHOTOPERIODS ON GROWTH AND DEVELOPMENT OF WHEAT

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PHOTOPERIODIC responses of crop plants have been extensively investigated and hypotheses have been put forward by a large number of workers regarding the mechanism by which flowering is induced or inhibited under specific photoperiods. A comprehensive survey of these problems has been recently made by Murneek and Whyte (1948). Work on photoperiodism in the tropics, however, is of a recent date (Sircar, 1948). Singh, Kapoor and Choudhri (1938) showed that wheat did best in 15 hours continuous illumination. Pal and Murty (1941) and Kar (1942-43) found that an exposure of low temperature treated seeds to long days induced earliness in all the wheat varieties. Nanda and Chinoy (1945) noted that long photoperiods as well as short photoperiods, after the completion of photostage, increased pollen sterility, while with natural day length sterility is very much lower. This indicated that beyond a certain extent, long days have only an adverse effect. Pal and Murty (1941) further noted that English Wheat grown under tropical conditions required chilling followed by long days for inducing earliness. In the absence of chilling long days have no effect. In Indian Wheat, on the contrary, chilling is not as important as long days for vernalisation. For yield and normal growth, low temperature was an essential feature; as in summer sowing, the crop yield becomes poor.

The present paper is an attempt to throw further light on the photoperiodic responses of wheat under the soil and climatic conditions of Bikaner (Lat.  $28^{\circ}1' N.$ ; Long.  $73^{\circ}22' E.$ ) and indicates the nature of interaction between variety, age of plant, and photoperiod on the growth characteristics of the wheat plants.

## MATERIAL AND METHOD

Three varieties of wheat, namely NP 165 (early), C 13 (medium) and Kubanka (late ripening), were sown on 1st November 1949 in the plots attached to the Department of Botany. Three plots each 10 ft.  $\times$  5 ft. in dimensions were selected for experimentation. Each of these was then divided into three sub-blocks 3 ft.  $\times$  5 ft. in size, separated by 6 inches broad ridges in between. These sub-blocks were sown with one of the three varieties arranged at random side by side with other varieties. All the plots were evenly manured with farmyard manure and sulphate of ammonia at 30 lb. N (half and half mixture) per acre. One of the main plots was provided continuous light, the normal sunlight being supplemented by two 100 Watts electric lamps

hung at a distance of 2 ft. above the plants. The second main plot was sun illuminated for a period of 6 hours (10 A.M. to 4 P.M.) every day, while for the rest of the day the plot was covered with a black curtain. The third plot was exposed to normal sunshine and acted as control. Care was taken to screen off continuous light so that other plots were not affected.

Short day treatment included 6 hours photoperiod from seedling stage to flowering, while long day (24 hours) treatment consisted of continuous illumination from the seedling to flowering stage. Under Bikaner conditions the average length of day varies as follows:—November 10·45, December 10·25, January 10·35, February 11·10, March 12·0, April 12·50, and May 13·30 hours per day. Additional illumination beyond these intervals was given by electric light.

The experiment thus involved the study of the effects of 3 photoperiods on three varieties of wheat at successive stages of the life-cycle. All observations were recorded at intervals of 30 days on 6 to 10 plants selected at random from each variety under the three photoperiodic treatments. Characters studied included (a) external growth attributes, (b) fresh and dry weights of plants, (c) number and weight of grains per sample, and (d) maturation period. All observations on dry weight were subjected to statistical analysis.

#### EXPERIMENTAL FINDINGS

A. *External growth characters.*—Plants were taller under normal conditions of illumination when compared with those growing under 6 hours or in continuous light; the poorest stand was recorded in the 24 hours photoperiod. Kubanka showed the maximum height, while NP 165 was poorest under all light treatments. Continuous light had detrimental effect on leaf number, while plants under normal photoperiod showed maximum number of leaves. Kubanka was again the best, while NP 165 was the poorest. Tillering was affected in a similar fashion, with best response in normal illumination. NP 165 showed the largest tillering under all the three light treatments, while Kubanka showed poor tillering under both normal and 6 hours photoperiod. Similarly, the number of ears was least in continuous light, and maximum in normal light. In general, continuous light under the conditions of experiment showed harmful effect on all external growth characters in the three varieties (Table I).

B. *Dry matter accumulation.*—The dry weight of plants was highest under normal light and lowest in continuous illumination. Among the varieties NP 165 appeared better under normal and 6 hours illumination, while Kubanka was better under continuous light. C 13 recorded lowest dry weight under all conditions. So far as the dry matter accumulation in component parts was concerned, the maximum dry weight of roots, stem and leaf was recorded in normal light, and least under continuous illumination. While this was true of all the varieties, some preferential relation between period of illumination and dry weight of different parts was recorded. Thus under 6 hours illumination NP 165 evinced maximum root dry weight; C 13 recorded



TABLE I

*Growth characters of wheat varieties under different photoperiods*

		6 hours†			Normal light†			24 hours*		
		V <sub>1</sub>	V <sub>2</sub>	V <sub>3</sub>	V <sub>1</sub>	V <sub>2</sub>	V <sub>3</sub>	V <sub>1</sub>	V <sub>2</sub>	V <sub>3</sub>
Height (cm.)	..	39.8	40.2	52.0	43.7	45.5	58.5	31.2	36.4	45.2
Leaf number	..	3.8	4.2	5.5	4.2	4.5	5.2	3.5	4.1	4.2
Tiller number	..	13.5	11.5	9.2	18.3	13.8	12.2	8.2	6.6	8.0
Ear number	..	12.8	7.8	5.3	17.2	9.5	6.6	6.7	5.6	6.2
Dry weight per plant (gm.)										
Dry weight of single plant		25.6	20.3	25.1	45.6	35.3	39.6	8.8	7.3	9.7
Leaves	..	6.0	6.0	11.3	11.3	8.4	15.0	1.6	1.5	2.3
Stem	..	8.7	9.3	8.4	13.5	11.1	12.2	2.7	2.3	3.7
Roots	..	2.4	1.6	2.3	6.6	7.4	8.1	1.3	0.7	0.7
Ears	..	8.5	3.4	3.1	12.4	8.4	4.4	3.2	2.9	2.8
Yield per plant (gm.)										
105 days	..	0.4	Nil	Nil	0.8	Nil	Nil	1.8	1.6	1.4
135 days	..	4.3	2.0	1.6	6.3	4.4	2.1	Plants harvested		
Number of grains										
105 days	..	Shrivelled	No grains		Shrivelled	No grains		60	42	41
135 days	..	144	52	44	215	110	61	Plants harvested		
Time taken for flowering and maturation (in days)										
Flowering	..	82	97	130	76	86	124	54	55	60
Maturation	..	150	165	180	150	160	175	125	125	130

\*Observations at 105 days.

†Observations at 135 days.

V<sub>1</sub> = NP 165.

V<sub>2</sub> = C 13.

V<sub>3</sub> = Kubanka.

maximum dry weight of stem under similar conditions; Kubanka showed maximum leaf dry weight under all conditions. Highest ear dry weight was also recorded for normal light and least for continuous

illumination. NP 165 appeared the best in so far as this character was concerned, followed by C 13 and Kubanka in decreasing order (Table I).

*C. Flowering, maturity and grain characters.*—In all the three varieties earliness was induced by continuous light as compared to normal illumination. Ear formation was earlier by 22 days in NP 165, 31 days in C 13 and 64 days in Kubanka. Reduced illumination period, on the contrary, increased the period of initiation of flowering by 6–11 days in different varieties. Photoperiods also induced variation in flowering dates by 10–48 days under normal light, 15–48 days under 6 hours and 1–6 days in continuous light. Similarly period of maturity in all the three varieties was reduced from 25–45 days under continuous illumination, while practically no change was noted under 6 hours illumination. Varietal differences in maturity period were more marked under normal and reduced light, but not so marked in 24 hours photoperiods.

At 105 days in the life-cycle no grain formation in C 13 and Kubanka was observed under normal and 6 hours photoperiods. NP 165, however, did show some grain formation under such conditions. Under continuous illumination all varieties showed grain formation, but varietal differences were less marked. At 135 days, however, some grain formation took place even under normal and 6 hours duration in all varieties. Normal light plants showed higher yield.

#### DISCUSSION

A critical examination of the growth characteristics of the three varieties shows marked varietal and photoperiodic responses. The variations in dry matter accumulation show that the effects of varieties, photoperiods and age of plants are highly significant. Of these, age appears to be a more potent factor than varieties in so far as dry matter accumulation is concerned. Interaction between age  $\times$  photoperiod, variety  $\times$  photoperiod, and variety  $\times$  age are also significant, indicating thereby that better growth of wheat plants is possible by congenial blending of these controllable factors of growth (Table II).

Taking the interrelation between age and photoperiod into consideration, it is noted that advance in age consistently improved the dry weight of the plant, while increasing photoperiod beyond the normal 12 hours duration is markedly deleterious. That these increases in dry weight in response to age and dry weight decrease in light durations higher than 12 hours are highly significant. At each age plants grown under normal illuminations were consistently better than those grown under 6 or 24 hours photoperiod. Even as early as 45 days photoperiodic effects were found to be highly significant (Table II *b*).

When the overall age values are taken into consideration varieties show highly significant differences under different photoperiods. Under low illumination no marked differences amongst varieties are evident on account of limited period during which synthetic processes leading to dry matter accumulation were allowed to continue. It is only when



the illumination period is raised to normal conditions that maximum growth is recorded. Under such conditions NP 165 is distinctly better than C 13 which in its turn is superior to Kubanka (Table II c). If the duration of light is further raised to 24 hours duration, a limit is imposed on the growth processes as a result of which imperceptible varietal differences are marked. Several explanations to this depression in growth activity may be given. For instance, excessive illumination may cause solarisation of the chloroplast and inactivate their synthetic efficiency. It may lead to excessive accumulation of meta-

TABLE II  
*Dry matter in relation to different factors*  
*a. Analysis of variance.*

Serial No.	Due to	D. F.	S. S.	M. S. S.
1	Samples	.. 5	17.55	3.51
2	Varieties	.. 2	694.35	347.17
3	Photoperiods	.. 2	4932.66	2466.33
4	Age	.. 3	15424.00	5141.33
5	Age × Photoperiod	.. 6	5052.76	842.13
6	Variety × Photoperiod	.. 4	955.12	238.78
7	Variety × Age	.. 6	237.93	39.66
8	Residual	.. 187	1881.77	10.06
9	Total	.. 215	29195.14	

S.E. per observation =  $\pm 3.2$ .

*b. Age × Photoperiod interaction*

Photoperiods (hours)		Age in days				Mean of 72
		45	75	105	135	
24	..	1.1	6.7	8.6	8.6	6.3
Normal	..	0.9	10.8	20.6	38.9	17.8
6	..	0.6	4.4	12.8	23.6	10.3
Mean of 54	..	0.9	7.3	14.0	23.7	

TABLE II—(Continued)  
c. Variety  $\times$  Photoperiod interaction

Photoperiods (hours)		Varieties			Mean of 72
		NP 165	C 13	Kubanka	
24	..	6.4	5.6	6.9	6.3
Normal	..	24.1	16.6	12.8	17.8
6	..	11.3	10.2	9.5	10.3
Mean of 54	..	13.9	10.8	9.7	

d. Variety  $\times$  Age interaction

Varieties		Age in days				Mean of 72
		45	75	105	135	
NP 165	..	0.9	10.3	19.1	25.5	13.9
C 13	..	1.0	6.8	14.4	20.9	10.8
Kubanka	..	0.7	4.8	8.6	24.7	9.7
Mean of 54	..	0.9	7.3	14.0	23.7	

S.D. for two means of 18 = 1.05

24 = 0.91

54 = 0.60

72 = 0.53

bolites—products of photochemical reactions, which may interfere with further synthesis of organic compounds. It may also involve high temperature effects under continuous illumination whereby various chemical and enzymatic reactions may be altered. Long photoperiods cut short the dark period so essential for efficient functioning of photosynthetic process in plants and in fact what is attributed to the long photoperiod may as well be due to short dark period of growth. It appears that for balanced vegetative and reproductive growth a certain minimum of this dark phase is absolutely essential.

Varietal growth is also found to be different at successive stages irrespective of the photoperiod under which the plants grow. As early as 45 days in the life-cycle C 13 evinced significantly better growth than Kubanka, but as age advanced NP 165 excelled C 13 and Kubanka. At the final stage, however, differences amongst early and late varieties



are less evident (Table II *d*). It appears therefore, that during early stages, growth processes of early and medium varieties proceed at a faster rate, while towards the end Kubanka, the late variety, shows higher efficiency of dry matter accumulation than the early varieties.

# SUMMARY

The effects of three photoperiods of 6 hours, normal and 24 hours were investigated on three varieties of wheat, NP 165, C 13 and Kubanka under Bikaner conditions of soil and climate, in terms of external growth characteristics, dry matter accumulation, flowering time and maturation.

In general plants under normal illumination exhibited better growth than similar plants grown under continuous illumination, which indicates a marked harmful effect on height, leaf number, tillering, number of ears and dry matter accumulation.

Flower initiation was earlier by 22 days in NP 165 under continuous light; earliness by 31 days in C 13 and 64 days in Kubanka was also recorded under similar conditions. Delayed flowering was characteristic in reduced light treatments. Continuous light also reduced maturity period by 25 days in NP 165, by 35 days in C 13 and by 45 days in Kubanka. Final yield of grain was, however, much below that recorded for normal or 6 hours illumination.

Significant interaction between variety and photoperiod, between photoperiod and age and between variety and age indicates that efficient dry matter accumulation requires congenial blending of these conditions of growth.

# ACKNOWLEDGEMENT

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# A STUDY OF THE SOIL ALGÆ OF A JUST DRIED UP POND\*

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WITH a view to study† the distribution and periodicity of algæ of 6 ponds on the Hadley Common, Hertfordshire, England, the writer started work in January 1947. The 6 ponds referred to were: Fish pond, Shallow pond, Brewery pond, Horse pond, Railings pond and Lemna pond. Of these, however, the Shallow pond dried up towards the beginning of August 1947. By about the middle of the third week of July the water level was very low. It was felt at this stage that a study of the algæ present in and grown from this soil, on being treated differently, would be worth-while, especially after having studied the periodicity of the algæ of the pond during the first 6 months of the year.

## EXPERIMENTAL PROCEDURE

The dry soil was collected on 11-8-1947 from three different spots in the pond about 3 feet from the edge and at approximately equal distances. At each spot, a cube of soil, about 10 cm. in edge was lifted. The 3 portions were mixed and dried in the laboratory in a paper-covered glass trough for 2 days.

Nine portions of this dry soil were taken (50 gm. each roughly) and treated, in triplicate, with distilled water, Knop's solution and Molisch's solution—100 c.c. to each portion. The containers used were jam jars with glass lids. The algæ that came up in these cultures were estimated after 12, 28, 70, 130 and 191 days. Each estimate was the average of all algæ counted in 30 high power fields of the microscope, each set of 10 fields chosen at random on two slides corresponding to each of the three replicates. The pH of the culture media was determined on the days when counts were made.

When the soil in the pond was still wet, *i.e.*, on 6-8-1947, a portion of the soil obtained by mixing three equal portions collected at three spots in the pond was brought to the laboratory and each of the three 50 gm. portions was kept in 100 c.c. of distilled water on the same day. The objects of studying the wet soil, in addition to the dry one, were two: (1) to find whether the wet soil would show any algæ different in form, especially as regards perennation, or in numbers from those grown from the dry soil and (2) to compare the pH of the 'wet-soil medium' with that of the 'dry-soil media' mentioned above and determine the effect on algæ of the difference in pH, if any. The algæ growing in these 'wet soil' cultures were estimated periodically. The first

\* Part of a thesis approved for the Ph.D. degree of the University of London.

† The results of this study have been recorded in a separate communication.



estimate was made 6 hours after treating the soil and the further counts were made after 3, 6, 19, 35, 77, 137 and 198 days. Here also the pH of the medium was determined periodically.

During the earlier part of the observations the cultures were kept on a table in the room and during this period (August to October 1947) the days were warm and bright. In November 1947 the cultures were removed to the illuminated window box in the laboratory. Barring the difference in the nature of illumination, the cultures were in bright light all the time.

#### OBSERVATIONS

The dry soil in distilled water showed an increase in the 'total algæ' upto 70 days, there being no significant change later. This increase was mainly due to *Euglena mutabilis*, *E. intermedia* and other Euglenineæ. The green algæ and diatoms were in the same small numbers throughout. The medium was all the time acidic and showed no great variation—the values ranging from 6.7 to 6.95 (Fig. 1, A).

The dry soil in Knop's solution showed more or less the same 'total algæ' upto 130 days but after 191 days the number was high. The diatoms, specially *Synedra tabulata*, were on the increase while Euglenineæ decreased in number. The green algæ, however, like in distilled water, showed no great change during the time. The medium which was acidic—5.9—to start with turned alkaline (7.4) as noticed after 191 days (Fig. 1, B).

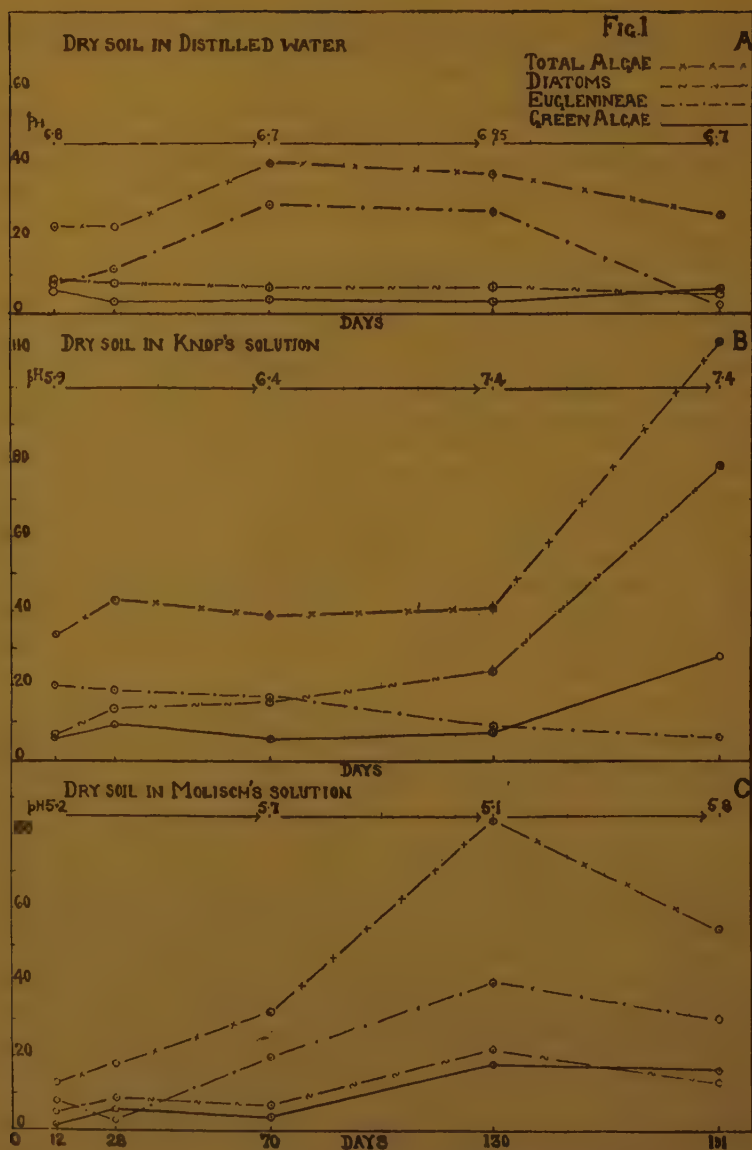
In Molisch's solution, the total of algæ steadily increased upto 130 days and there was a fall towards the end. All the three groups of algæ—Euglenineæ, Diatoms and Green Algæ increased in numbers, especially the first. The pH of the medium was distinctly acidic all the time, ranging from 5.1 to 5.8 (Fig. 1, C).

The wet soil in distilled water showed an abrupt rise of total algæ on the 3rd day and after the 19th day the numbers were more or less steady (Fig. 2). This abrupt rise was on account of *Chlamydomonas* spp. As seen in dry soil treated with distilled water and Molisch's, here also the Euglenineæ were on the increase all the time, though not to the same significant degree. Barring the *Chlamydomonas* spp. referred to, the green algæ and diatoms remained more or less steady all the time. The medium was distinctly acidic upto the 137th day, the range being 4.1 to 4.8 and towards the end, the reading was 5.9.

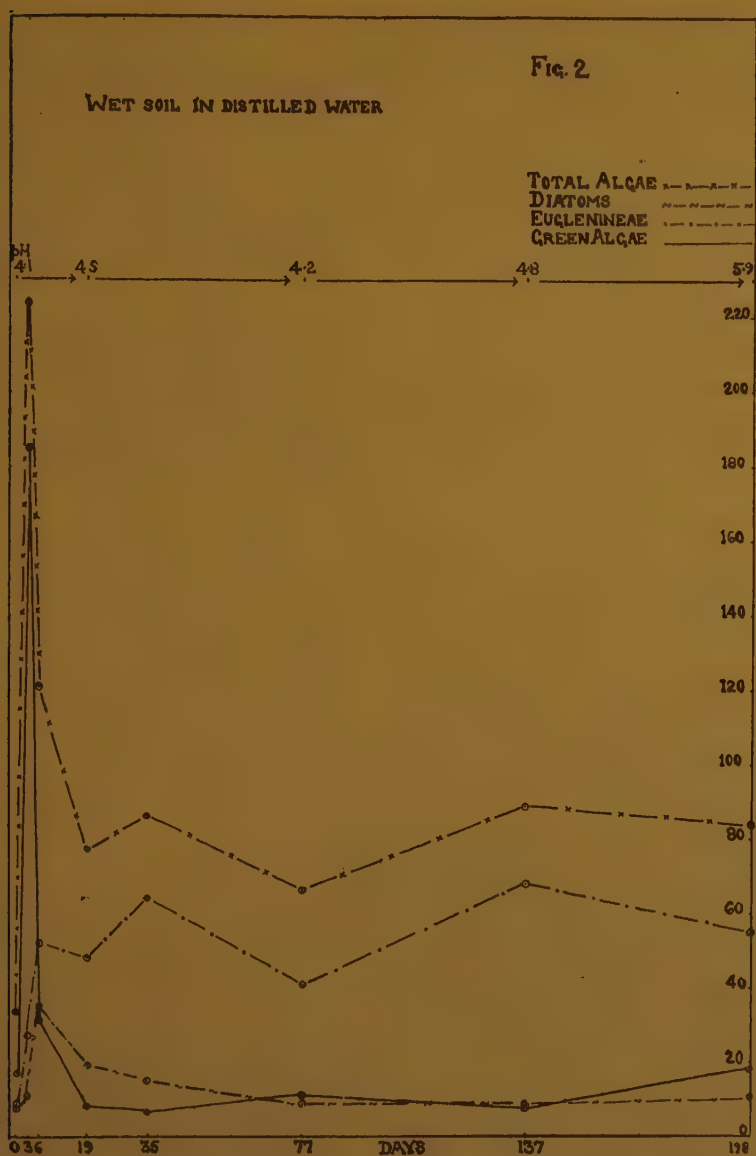
Either in this medium or in those referred to above no resting stages of algæ were observed.

#### CONCLUSIONS

The average pH (6 months' average) of the water of this pond was 6.5 and the water was relatively rich in iron throughout. From the field data, it was inferred that this pond harboured a large bulk of Euglenineæ on account of the water being acidic and rich in iron. The



indoor observations on the soil of this pond supported the detail inferred from nature. The acidic culture medium encouraged an abundance of Euglenineae (Fig. 1, A & C) especially *Euglena mutabilis*. In nature this alga was conspicuous in this pond and also in the other acidic ponds. Lund (1942) described *Euglena mutabilis* as favouring acidic conditions both in field and cultures. Species of *Euglena*, in fact, thrive best in acidic conditions. Harris (1941) noted a purer growth



of *Euglena viridis* when pH was between 4 and 6. Jahn (1931) and Alexander (1931) found *Euglena gracilis* growing best under acidic conditions.

A change in the culture medium from acidity to alkalinity as noticed in Knop's (from 5.9 to 7.4) appeared to have an effect on the algæ growing therein. Diatoms specially *Synedra tabulata* and *Pinnularia*



*subcapitata* showed an increase while Euglenineæ fell in numbers. This was in accordance with the conclusion drawn through the field data that diatoms were more numerous and Euglenineæ fewer in alkaline ponds than in acidic ones. It could not be explained why the Knop's medium alone should show a change from acidity to alkalinity along with time although Hopkins and Wann (1926) say that in unbuffered nutrient solutions marked changes in H-ion concentration may be brought about by unequal absorption of ions. The pH values of the untreated Knop's solution and Molisch's were 7.4 and 7.1 respectively as determined 200 days after their being prepared. The initial pH values were not determined because a change in pH on being treated with soil was not anticipated.

Of the three media—distilled water, Knop's and Molisch's—the last one showed greater acidity and it was in this medium that Euglenineæ were noted to be most predominant. This was in accordance with the inference from field data that a distinctly acidic water harboured a predominantly flagellate flora. Some green algæ also were comparatively abundant in this medium. It was of interest to note that those green algæ that were dominant in distinctly acidic waters in nature, e.g., *Microthamnion kutzingianum*, *Closterium kutzingii* and species of *Characium*, contributed to this richness. Lund (1942) too observed in cultures *Microthamnion kutzingianum* and *Characium Pringsheimii* favouring very acidic conditions, e.g., pH 4.0 to 5.0.

The wet soil in distilled water, besides showing the initial sharp rise in "total algæ", was richer in algal content than the dry soil treated with the three media (Fig. 2). This could obviously be due to there being more algæ in a vegetative state in wet soil than in a dry one. In an attempt to resist drying, it could reasonably be expected that only some algæ survive.

The pH of the "wet-soil distilled water medium" was much less through the period of observation than that of the three media treated with dry soil. Just before the pond dried up, the pH of the water was 4.9 and pH of the "wet-soil distilled water" medium was ranging from 4.1 to 4.8. The conditions did not very much alter the degree of acidity at which algæ in nature were thriving just before the pond dried up and the greater abundance of algæ in this medium therefore could be attributed to the maintenance of more or less the same degree of acidity in the laboratory medium as in nature. Thus in respect of this medium being comparatively rich in algæ, two features become relevant: (1) continuity of life facilitated by the soil being wet and (2) the degree of acidity of the pond water just before the pond dried up and that of the laboratory medium being more or less the same.

Blue green algæ were not observed in any of these cultures during the period when the other algæ were present and this must be due to the fact that the soil was highly acidic before being cultured. But when the cultures finally dried up after nearly 10 months the surface of the soil was closely examined. Soil surfaces which had been bathed by Knop's solution and distilled water showed signs of algal growth. A thin greenish coat on the surface of the soil in the Knop's cultures

was composed of pure *Oscillatoria splendida*. The reddish brown growth observed at the same time on the surface of the soil in the "dry-soil distilled water cultures" was due to *Phormidium laminosum* and colonies of *Nostoc*. The species was not identified as the colonies were without spores. At this time the soil in the other two cultures was not dry.

A month later, however, the soil surface of these two cultures, *i.e.*, Molisch's and "wet-soil distilled water" cultures—was exposed, but no visible growth of any alga was noticed. Even a microscope examination of the soil surface did not show any algæ.

It has been pointed out already that the pH of the Molisch's medium and the "wet-soil distilled water" medium was lower throughout than that of the two others (Knop's culture and "dry-soil distilled water" culture). The higher acidity of these two media might not have encouraged the growth of blue-green algæ which again would support the conclusion arrived at through field observations that blue-green algæ did not favour highly acidic waters.

#### SUMMARY

The relative numbers of algæ, that came up in the laboratory cultures set up by treating the dry soil of a just dried up pond with distilled water, Knop's solution and Molisch's solution showed variations and an attempt was made to explain these variations on the basis of field observations on this pond and the other ponds in the area.

A change of pH in the Knop's medium from acidity to alkalinity reduced the number of Euglenineæ and increased the number of diatoms; this being in accordance with the conclusion drawn through the field data that diatoms were more abundant in alkaline water than in acidic ones.

The dry-soil treated with Molisch's solution was more acidic than the other "dry-soil media" and the greater abundance of Euglenineæ in this medium was again in agreement with the field observation that a distinctly acidic water and an abundance of flagellates went together.

The algæ that appeared on the wet-soil of the drying pond after distilled water had been added were comparatively more numerous than those observed in dry soil similarly treated.

Blue-green algæ were not noticed in any of the cultures, during the period of observation, and the field observation that blue-green algæ were frequent in highly acidic waters was given as a reason for this absence. When the cultures finally dried up, however, blue-green algæ appeared on the soil previously present in Knop's solution and distilled water (dry soil treated with distilled water).

The author is indebted to Professor F. W. Jane, Ph.D., D.Sc., for his guidance and criticism during the course of this work. He is also grateful to Professor W. H. Pearsall, D.Sc., F.R.S., for his interest in the work and for his helpful criticism.

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# THE GENUS *PALLAVICINIA* GRAY IN INDIA

## 1. *Pallavicinia canarus* St.\*

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(Received for publication on October 23, 1953)

### INTRODUCTION

THE genus *Pallavicinia* Gray, of the older systematists has been split up now into three genera, namely, *Pallavicinia* Gray, *Moerckia* Gottsche and *Makednothallus* Verdoorn. It is equivalent to Lindberg's sub-genus *Eu-pallavicinia*, as defined by Schiffner (1909), and to Stephani's group *Procumbentes*. In this restricted sense it includes about 30 species. Evans (1939) has given a critical and comprehensive account of the history of the genus.

In India *Pallavicinia* is represented by about half a dozen species distributed as follows:—

1. *P. ambiguous* (Mitt.) St.—Assam, Khasia mountains.
2. *P. canarus* St.—Canara.
3. *P. himalayensis* Schiffn.—Sikkim-Himalayas, Kurseong.
4. *P. decipiens* (Mitt.) St.—Ceylon.
5. *P. indicus* Schiffn.—Nepal.
6. *P. crispatus* (Mont.) St.—Nilgherry mountains.

In 1936, Pandé and Misra collected a species of *Moerckia* from the neighbourhood of Khati (7,200 ft.), Western Himalayas. Apparently this is the first record of this genus from India.

Ghosh and Chakravarty (1943) reported an undertermined species of *Pallavicinia* from Dacca, describing some taxonomic features of the species but, as far as the authors are aware, no detailed work has been done so far on the genus in this country. The present paper deals with the taxonomy of *P. canarus* St., a species established by Stephani (1917, p. 62) on the basis of a specimen collected by Pfeleiderer from Canara, in the Western Ghats. The plant is known so far only from its Latin diagnosis (Stephani, 1917, p. 62) which consists merely of the vegetative features of the thallus and the involucre.

Besides the type locality, *P. canarus* has been frequently collected from other parts of the country as well (e.g., Madhya Pradesh, Pachmarhi, Misra, 1949, Pandé and Srivastava, 1951; Western Ghats, Travancore, Pillai, 1951; Agumbe, Pandé and Srivastava, 1950; and Mahabalé, 1951 and 1952). The present paper attempts to give a complete account of the species based largely on specimens collected from Agumbe and Pachmarhi.

\*Contribution from the Department of Botany, Lucknow University, New Series, No. 7.

## DESCRIPTION

*P. canarus* grows at Pachmarhi during the monsoon months and forms dense clusters along the water courses and channels. Its most favourable habitats are the shady sides of the perennial streams, and the slopes and sides of the waterfalls, where the plants are frequently bathed by the stream or receive a constant spray of water from it. It is often associated with *Dumortiera hirsuta* R. Bl. et Nees and *Riccardia levieri* Schiffn. Sometimes the plants may grow completely submerged under water. In such habitats the species shows very prolific growth. It multiplies mostly vegetatively and even the most vigorously growing plants, collected as late as February and March, do not develop generally any mature sporophytes.

The vegetative body of the plant (Figs. 1-4, 8, 11, 12) consists of a creeping prostrate thallus 2-6 cm. long and 3-4 mm. broad. It has a prominent midrib, and may be simple (Figs. 2, 11 and 12) or branched (Figs. 1 and 8). The midrib is about 5 mm. thick, and many layered (Fig. 5). Ventrally the thallus bears numerous, unicellular simple and hyaline rhizoids which anchor it to the substratum. Branching is profuse in plants growing under favourable conditions. It is either apical or adventitious. In the former case the branches arise from the apical cell and have their midrib and conducting tissues continuous with those of the main shoot (Figs. 1 and 8). Adventitious shoots arise from the ventral side of the midrib, and their midrib and the conducting tissues are not continuous with those of the main thallus (Figs. 3 and 4). Sometimes a plant may bear about a dozen adventitious shoots. Fig. 4 shows as many as 10 such shoots developing from a male plant.

The thallus is about 15 cells thick in the middle (Fig. 5) and has a central conducting strand consisting of about 30 thick-walled cells (Figs. 5 and 5a). The midrib gradually passes into a broad lamina one cell thick.

The size of the cells in the various parts of the thallus is somewhat variable. Marginal cells (Fig. 6a, *m.c.*) measure  $32 \times 62 \mu$ , submarginal cells (Fig. 6a, *sm.c.*)  $38 \times 50 \mu$ , cells about the middle of the wing (Fig. 6b)  $38 \times 54 \mu$ , cells near the costa (Fig. 6c)  $38 \times 76 \mu$ , upper epidermal cells above the midrib (Fig. 6d)  $25 \times 125 \mu$ , and midrib cells (in L.S., Fig. 7)  $28 \times 130 \mu$ . These observations on the vegetative structure of the thallus in general, agree with those of Stephani.

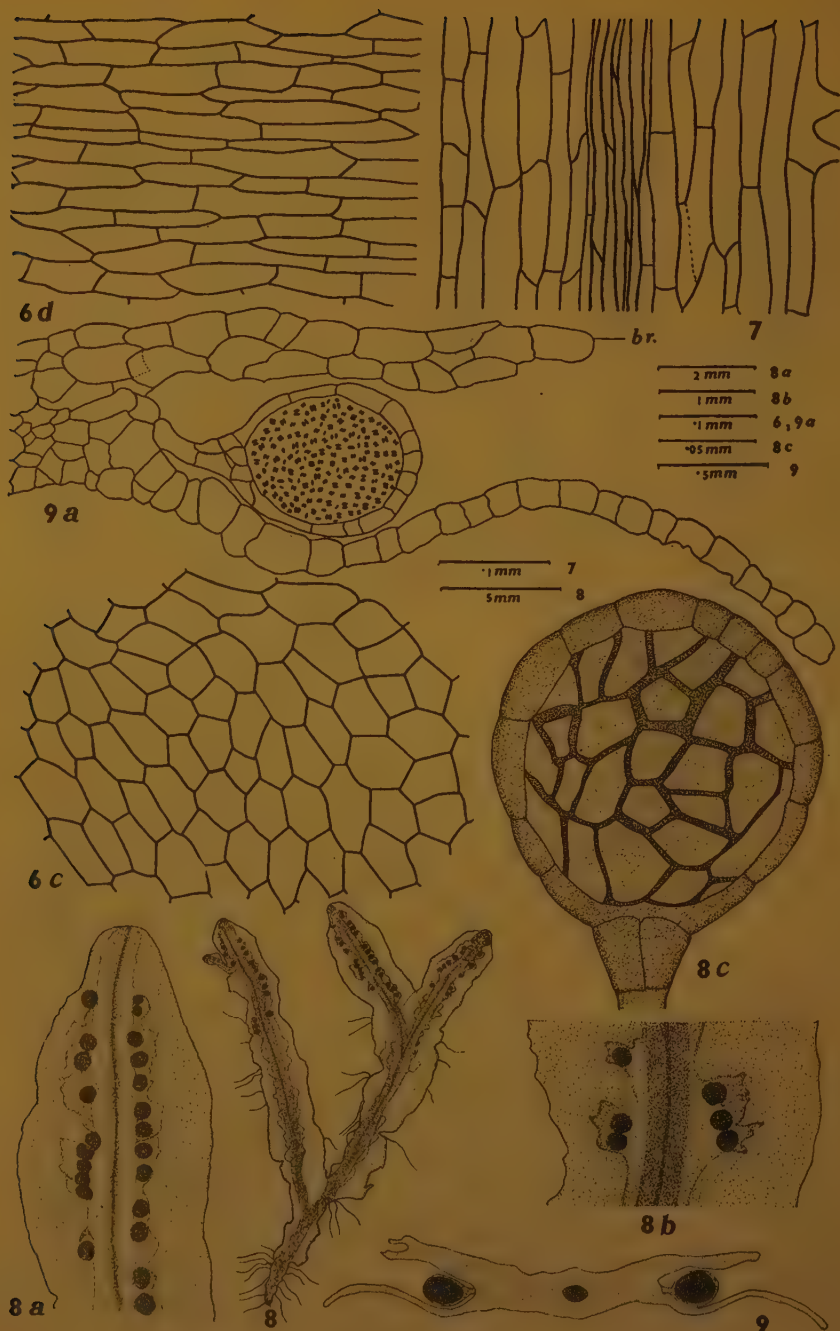
*P. canarus* is strictly dioecious and the sex-organs are borne on the dorsal surface of the thallus. The male plants (Figs. 4 and 8) are invariably smaller than the female (Figs. 1, 2, 3, 11 and 12), and in nature, the latter are apparently more abundant, although often these do not produce mature sporophytes. Obviously at Pachmarhi propagation by spores is rare and the species multiplies mostly by the separation of the vegetative branches. It is perennial along the permanent water-courses on this plateau, but under adverse conditions thick and, more or less, tuberous ventral shoots are formed which serve both for perennation and propagation.



FIGS. 1-6 b

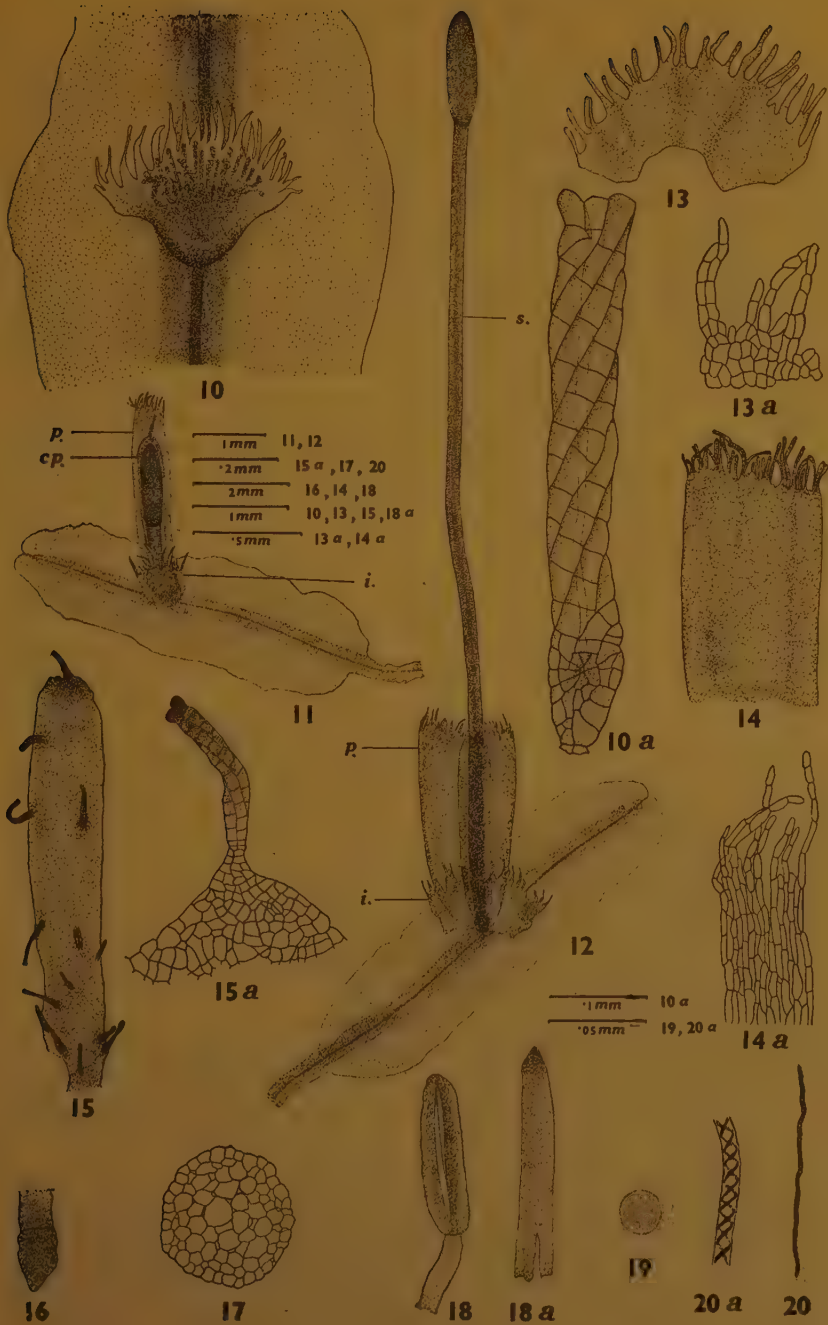
Fig. 1. Female thallus. Fig. 2. Thallus with mature sporophyte. Fig. 3. Female thallus with two ventral innovations (ventral view). Fig. 4. Male thallus with ten ventral innovations (ventral view). Fig. 5. T.S. of thallus (lamina on one side shown only partly). Fig. 5a. A part of the midrib showing conducting strand. Fig. 6a. m.c., marginal and sm.c., submarginal cells. Fig. 6b. Cells from near the middle part of lamina.





FIGS. 6c-9a

Fig. 6c. Cells adjoining midrib; Fig. 6d, midrib cells in surface view. Fig. 7. L.S. midrib. Fig. 8. Male thallus. Note the arrangement of antheridia. Fig. 8a. A part of the above. Fig. 8b. A part of male thallus showing antheridia and bracts. Fig. 8c. Antheridium. Fig. 9. T.S. of male thallus showing attachment of antheridia. Fig. 9a. A part of the above; br., bract.



Figs 10-20 a

Fig. 10. Part of female thallus with receptacle. Fig. 10 *a*. Archegonium, note the twisted neck. Fig. 11. Thallus with a young sporophyte enclosed within the perianth, *p.*, and the calyptra, *cp.* Fig. 12. Thallus with mature sporophyte. Involucre and perianth opened out. Fig. 13. Involucre dissected out. Fig. 13 *a*. Portion of the above. Fig. 14. Perianth dissected out. Fig. 14 *a*. Portion of the above. Fig. 15. Calyptra. Note the unfertilised archegonia carried by the calyptra. Fig. 15 *a*. Apex of calyptra. Fig. 16. Foot. Fig. 17. T.S. of seta. Fig. 18. Mature capsule. Note incomplete dehiscence. Fig. 18 *a*. A valve. Fig. 19. Spore. Fig. 20. Elater. Fig. 20 *a*. Part of elater.

*The Antheridium.*—The antheridia develop in acropetal succession and occur in a row on either side of the midrib (Figs. 8, 8 *a* and 8 *b*). They are protected by a shelf-like toothed or lobed covering, the *involucre*, which develops from the scales or *male bracts*. The antheridia may occur in a long continuous row or may be interrupted by patches of sterile tissue. The mature antheridium has a spherical body borne on a short stalk (Figs. 8 *c*, 9 and 9 *a*) and is attached obliquely to the lateral side of the midrib. It is more or less directed forward. The longitudinal diameter of the antheridium is about 160–80  $\mu$ , and its wall is single layered and about 20  $\mu$  thick. It is filled with numerous biciliate sperms.

*The archegonium.*—The archegonia occur in clusters on the dorsal surface of the midrib (Figs. 1 and 10). They are enclosed by a protective covering, the *involucre*. Within the involucre each archegonium is surrounded by another protective sheath, the *perianth*. The latter is represented by a few scales before fertilisation, and is inconspicuous. After fertilisation it becomes very prominent and forms a long cylindrical sheath around the developing embryo and mature sporophyte (Figs. 11, *p.*, and 12, *p.*). A thallus may bear one, two or more groups of archegonia. In plants from Pachmarhi the authors have often observed as many as half a dozen archegonial involucre with archegonia in different stages of development on a single plant. The mature archegonium has a long twisted neck and a somewhat dilated ventre (Fig. 10 *a*). The neck consists of 5 tiers of cells and encloses the neck-canal cells in the centre. It is 400–600  $\mu$  long and 40–50  $\mu$  broad. In an involucre generally only one archegonium develops into mature sporophyte, while the rest of them degenerate.

*The perianth.*—The perianth is oblong and cylindrical (Fig. 11, *p.*). Its mouth is open and the margin bears long hair-like processes (Figs. 14 and 14 *a*).

*The calyptra.*—The calyptra (Fig. 11, *cp.*) is shorter than the perianth and is invariably enclosed by it. It carries all over its body the remains of the unfertilised archegonia (Fig. 15).

*The involucre.*—The mature involucre (Fig. 11, *i.*), as stated by Stephani (1917, p. 62), is more or less cupulate and its mouth is fringed with a number of thick hairs which are sometimes branched (Figs. 10, 11, *i.*; 12, *i.*; 13 and 13 *a*), as described by Stephani. In *P. crispatus* (Mont.) St. (Stephani, 1900, p. 316) the involucre is shortly cylindrical and 4 or 5 lobed, the lobes extending upto the middle.

*Sporophyte.*—The sporophyte (Figs. 2 and 12) consists of a cylindrical capsule, a long seta and a conical foot. While young (Fig. 11)



it is enclosed within the calyptra, which arises from the neck of the archegonium.

The mature sporophyte is about 3–4 cm. long, and bears a capsule 3 mm. in length. The latter dehisces by 4 valves that remain attached at the apex (Fig. 18). The seta (Fig. 12, *s.*) is comparatively long and consists of parenchymatous cells (Fig. 17). The foot (Fig. 16) is more or less wedge-shaped and lies embedded in the thallus.

The spore (Fig. 19) is spherical, golden yellow and  $20\mu$  in diameter. The elaters are of the same colour as the spores. They are about  $650\mu$  long,  $6\mu$  broad and bispiral (Figs. 20 and 20 *a*).

#### SUMMARY

1. *P. canarus* grows in dense clusters during monsoon months in the Western Ghats and Pachmarhi.

2. The species is dioecious; male plants are invariably smaller than female plants.

3. The thallus has a prominent midrib and a broad lamina. The midrib is many cells thick and includes a conducting strand with thick-walled cells. The lamina is one cell thick.

4. The antheridia occur on the dorsal surface of the thallus in one row on either side of the midrib and are protected by an involucre from behind.

5. The archegonia occur in clusters along the midrib on the dorsal surface of the thallus. Each archegonial group is enclosed in an involucre within which lies the perianth. The mouth of the involucre is fringed with a number of thick hairs which are sometimes branched.

6. The mature sporophyte has a cylindrical capsule, a long seta and a wedge-shaped foot.

7. The capsule opens by 4 valves that remain attached at the apex.

8. The spores are spherical and  $20\mu$  in diameter, and the elaters are bispiral and  $650\mu$  long.

#### ACKNOWLEDGEMENT

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# A NEW SPECIES OF *PAECILOMYCES* FROM SOIL

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(Received for publication on November 3, 1953)

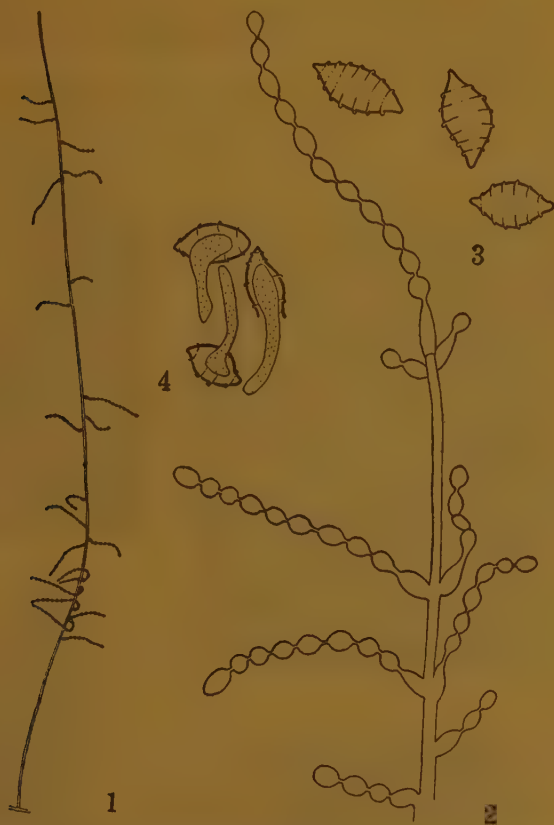
THE genus *Paecilomyces* was established in 1907 by Bainer with the type species *P. varioti*. Since then much confusion has prevailed regarding the characters which delimit the genus. Raper and Thom (1949), who have paid considerable attention to this genus, mention in their manual (p. 692), "Viewed in conjunction with the descriptions and figures found in the literature, the structural type here recognized as *Paecilomyces* is seen to be cosmopolitan and is found described under several generic names, including *Corollium*, *Spicaria*, *Penicillium*, *Paecilomyces*, *Eidamia*, *Byssochlamys* and perhaps others. No one at present knows this group well enough to establish sound lines of relationship among them." The genus is widespread and has been isolated from diverse environments in nature. No detailed monographic study has been made so far and the literature remains scattered. The present species was isolated from a soil sample collected from Patharia forest near Sagar in Madhya Pradesh.

## MATERIAL AND METHODS

The soil from Patharia forest was collected in August 1952, from a depth of about 3" with a sterile spatula, packed in a sterile container and brought to the laboratory. The soil was plated in different dilutions in Petri dishes of several media. The fungus first appeared on Waksman's agar. Further isolation and purification was done on Czapek's agar on which detailed observations were recorded. The fungus was later grown on potato dextrose agar, soil extract agar, Waksman's agar and malt agar for noting any variations and characteristics on these culture media.

## GENERAL STRUCTURE

The general structure of conidiophores (Text-Figs. 1-2; Pl. VIII, Figs. 2-4) agrees with the generic description of *Paecilomyces*. The shape of phialides (Text-Fig. 2; Pl. VIII, Figs. 2 and 4) is somewhat different. It resembles more the sterigma of a typical monoverticillate *Penicillium*, i.e., it is a cylindrical cell with an acute more or less tapering apex rather than having a narrowed long neck as is described typically for the genus *Paecilomyces* (Raper and Thom, p. 47, Figs. 11 B and 11 D). But the arrangements and distribution of the phialides are typical of the genus. The most remarkable characteristic of this species is the pattern of markings on the walls of conidia (Text-Fig. 3; Pl. VIII, Fig. 5). The species so far described have smooth walls but here a characteristic and beautiful pattern of markings in the form of spiral bands from end to end is noticeable. In view of these observations the fungus is described as a new species of *Paecilomyces*.



TEXT-FIGS. 1-4. Fig. 1. Single conidiophore showing the formation of conidial chains,  $\times 140$ . Fig. 2. Conidiophore showing the formation and shape of phialides and conidial chains,  $\times 595$ . Fig. 3. Conidia showing the typical spiral markings on the wall,  $\times 1,400$ . Fig. 4. Conidia, germinating,  $\times 1,400$ .

*Paecilomyces fusisporus* sp. nov.

Colonies on Czepek's agar broadly spreading with medium rate of growth, completely occupying the Petri-dish in 10 days at room temperature, low growing, with superficial growth consisting mostly of trailing fertile hyphæ, faintly zonate, surface white at first later becoming cream and slightly brownish (Pl. 12-6 B); reverse of the same colour but more brownish (Pl. 13-7 B). Vegetative hyphæ branched, hyaline,  $3-4\mu$  thick. Fertile hyphæ septate, branched, creeping. Conidial fructifications either terminal or on short branches of creeping or slightly erect hyphæ consisting of separate sterigmatic cells, or of verticils or series of verticils of branchlets and sterigmata irregularly distributed along the fertile hyphæ; sterigmata  $10-15 \times 3-5\mu$  with pointed apices bearing conidia in long chains  $100-125\mu$ ; conidia fusiform with the two ends usually pointed,  $6-10 \times 3-5\mu$ ,



brownish in colour, walls thick showing characteristic spiral markings from end to end. The species is unmistakable on account of the markings on the spores.

*Note.*—The plates refer to Maerz and Paul's "Dictionary of Colour".

Colonies cultæ in Czapek medio late diffusæ, ratione increment media, omnino implentes Petri patinam diebus decem sub temperatura normali cubiculi, crescentes depresso, partes superficiales constantes ut plurimum hyphis fertilibus repentibus, tenuiter zonatæ, superficie primo albida, tum crenea, tandem tenuiter brunnea; pars aversa eiusdem coloris sed plus brunnea. Hyphæ vegetativæ ramosæ, hyalinæ, 3–4  $\mu$  crassæ. Hyphæ fertiles septatæ, ramosæ, repentis. Fructificationes conidiales terminales vel insidentes ramis brevibus hypharum repentium vel tenuiter erecterum, constantium cellulis sterigmatibus separatis vel verticillis vel seriebus verticillorum ramorum et stergimatum irregulariter distributorum ad hyphas fertiles; sterigmata 10–15  $\times$  3–5  $\mu$  acuta ad apices, ornata conidiis in catenas longas 100–125  $\mu$  dispositis; conidia fusiformia utroque apice ut plurimum apice ut plurimum acuto, 6–10  $\times$  3–5  $\mu$ , brunneola colore, perietibus crassis ornatis lineis spiralibus characteristicis ex uno in alium apicem. Species distincta est ob sporarum signis.

#### CULTURAL CHARACTERISTICS

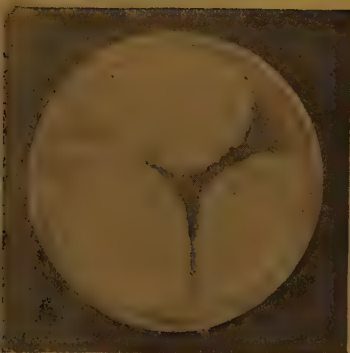
The fungus was grown on different media in order to note any variations or special characteristics. The fungus showed a fair constancy in the general morphology and range of measurements. The following peculiarities have been noted on different media.

*Soil extract agar*\*.—The radial growth was fast but the hyphæ were sparingly branched and conidiophores were also sparsely produced. The colony remained transparent without producing any marked thickness. Only a faint coloration developed in the older parts of colonies. The range of measurements of conidia and phialides remained the same as in Czapek's medium.

*Malt agar*.—The growth was fast. The succession of colour remained the same as in Czapek's agar but the shades were deeper; the reverse becoming almost black. In addition to the ordinary conidiophores, which are much branched and bear sterigmata and conidial chains all over, there were produced stiffer, unbranched dark brown conidiophores on which the phialides and conidial chains were crowded mainly towards the apical region (Pl. VIII, Fig. 3). Such conidiophores were few on Czapek's agar. Range of measurements of conidia and phialides remained the same.

*Potato dextrose agar*.—Growth was fast and colony thicker than on Czapek's agar, surface more flocculent, faintly zonate and colour darker, almost blackish on reverse in older colonies. Stiff conidiophores produced as in the case of maltagar.

\* 1,000 gm. of dry soil was autoclaved in a litre of water for 30 minutes. The solution was allowed to stand, decanted and filtered. 20 gm. of agar was added to the filtrate and water added to make it to one litre. 0.2 gm. of  $K_2HPO_4$  was added as buffer. The medium was then tubed and autoclaved.



1



2



3



4



5



6





*Waksman's agar*.—Growth was fast. The colony developed a distinct margin of about 3–4 mm. which was white and flocculent. Distinct zonations were formed which were discernible on the reverse as well. The colour succession remained the same but the shades were lighter. Stiff conidiophores were produced. The range of measurements remained the same.

*Spore germination*.—The germination was tried in pea decoction. The spores readily germinated in about 4–5 hours. Approximately 88% of spores were found to germinate. A single germ tube comes out from any part of the spore, *i.e.*, from apex or sides, by the rupture of the wall (Text-Fig. 4; Pl. VIII, Fig. 6). The outer ornamented thick wall remained unchanged except for the rupture or break. The inner wall produced the germ tube and the protoplasmic contents migrated into it. Growth and branching followed readily.

#### SUMMARY

A new species of *Paecilomyces* has been described. The conidia are fusiform in shape. They are characterised by a beautiful pattern of markings on the wall in the form of spiral bands from end to end.

Cultural characteristics were noted for several media. Besides the normal conidiophores a special type of stiff and sparingly branched conidiophores were also produced on several media. Germination of spores has also been studied.

#### ACKNOWLEDGEMENTS

The writer wishes to express his grateful thanks to Dr. R. K. Saksena of the Allahabad University for his valuable guidance and to Dr. Charles Thom for very kindly going through the descriptions along with the figures. His advice has been very useful. His thanks are also due to Prof. Fr. H. Santapau for the Latin diagnosis and to Dr. R. Misra for the facilities provided and kind encouragement.

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#### PLATE VIII

FIGS. 1–6. *Paecilomyces fusisporus* sp. nov.

- FIG. 1. Colonies on Czapek's agar, 10 days old.  
 FIG. 2. Habit showing the branched conidiophores, arrangement of phialides and chains of conidia,  $\times 150$ .  
 FIG. 3. Stiff conidiophores in which the phialides are crowded towards the apical region,  $\times 150$ .  
 FIG. 4. Two phialides showing the typical shape and the chains of conidia,  $\times 620$ .  
 FIG. 5. Conidia showing the fusiform shape and the typical spiral markings,  $\times 750$ .  
 FIG. 6. Conidia, germinating,  $\times 1,200$ .

# A SEASONAL STUDY OF THE SILT-ALGÆ OF TWO PONDS<sup>1</sup>

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(Received for publication on October 10, 1953)

DURING a twelve months' study<sup>2</sup> of the periodicity of algæ of five ponds on the Hadley Common, Hertfordshire, England, one idea gained prominence, namely that, some species noticed almost throughout the year—constant species as they are called—showed month after month striking changes in their frequency, apart from the "abundant species" becoming dominant at one time or other in the year to remain in traces or disappear at other times. The question arose as to what happened to the individuals of a species, when the abundance noticed one month declined in the next one or two months. Did the organisms pass into resting stages so as to be retained on the pond bottom till such time as the algæ reappeared in the cycle of periodicity? Lind (1940) in fact remarked that the resting period in life of most algæ would be spent in mud and that the growth of algæ in pond would depend largely on the extent to which resting stages germinate. Transeau (1913) likewise associated the periodical dominance of algæ with the germination of zygospores, oospores and aplanospores. To gain, however, a personal insight into the possible answer to the problem, the seasonal study of silt-algæ was undertaken. Through this study, it was also hoped to investigate whether any particular type of algal flora was confined to the silt as opposed to the general flora of the pond and if so, what relation such a flora holds to the nature of silt and to the seasonal variations.

## EXPERIMENTAL PROCEDURE

Two ponds showing a wide contrast in the algal flora were chosen for the study. One was the Lemna pond (characterised by a relatively poor flora) with a thick sheet of *Lemna minor* over the entire pond surface and with water having negligible or very small concentration of oxygen (varying from "0" to 2 mg./l.) and high concentrations of hydrogen sulphide, carbon dioxide, phosphate and silica. As discussed in the paper dealing with the distribution of algæ of this pond, this pond could be regarded as having a "reducing bottom". The silt of this pond, therefore, was thought suitable for the present study because it would afford one of an uncommon type. The second pond chosen was the Brewery pond showing a rich algal flora; the water of this pond showed a normal concentration of oxygen (between 6–12 mg./l.) during the year and judging from the other chemical features,

1. Part of a thesis approved for the Ph.D. Degree of the University of London.
2. The results of this study have been recorded in a separate communication.

the pond could be regarded as a normal one providing for this study silt of a common or normal type.

Small amounts of fine silt occurring on the sides (about 3' inside from the water edge) of each of the two ponds were collected from different spots by means of a wide-mouthed bottle fixed at the end of a collecting stick. The collection was made at the beginning of each of the four seasons of the year. A layer of silt about  $\frac{1}{2}$ " thick was provided in each of two glass dishes ( $2\frac{1}{2}$ " diameter and  $1\frac{3}{4}$ " depth) with lids. To the silt in one dish about 50 c.c. of distilled water were added and to another, the same quantity of pond water. A fortnight after the cultures were set up, the first estimate of algæ was made and the further estimates were made once a month during the season concerned and once a season during the rest of the year. (*Method of estimation:* The algæ of the silt surface in each dish were pipetted out along with the medium to have one drop placed on each slide. Each estimation was the average of all algæ counted in three sets, of ten each, of high power fields of a microscope, ten fields chosen at random—five on each of two slides—corresponding to each of the three replicates).

Once a month the media in the dishes were drained off carefully without unduly disturbing the silt at the bottom and fresh supplies put in so as to keep the cultures fresh all the time.

The pH of the drained off media was determined at intervals so as to be able to judge from the variations in the values whether the silt was remaining without being subject to the effects of decomposition.

The algæ present on the silt treated with distilled water were compared with those present on the silt treated with pond water and the algæ of one season compared with those of another. Further the seasonal variations in the flora of the two ponds were compared and the general succession in the two ponds studied.

#### OBSERVATIONS

##### (1) Silt from the Brewery Pond

*Winter silt* (collected at the beginning of 1948).

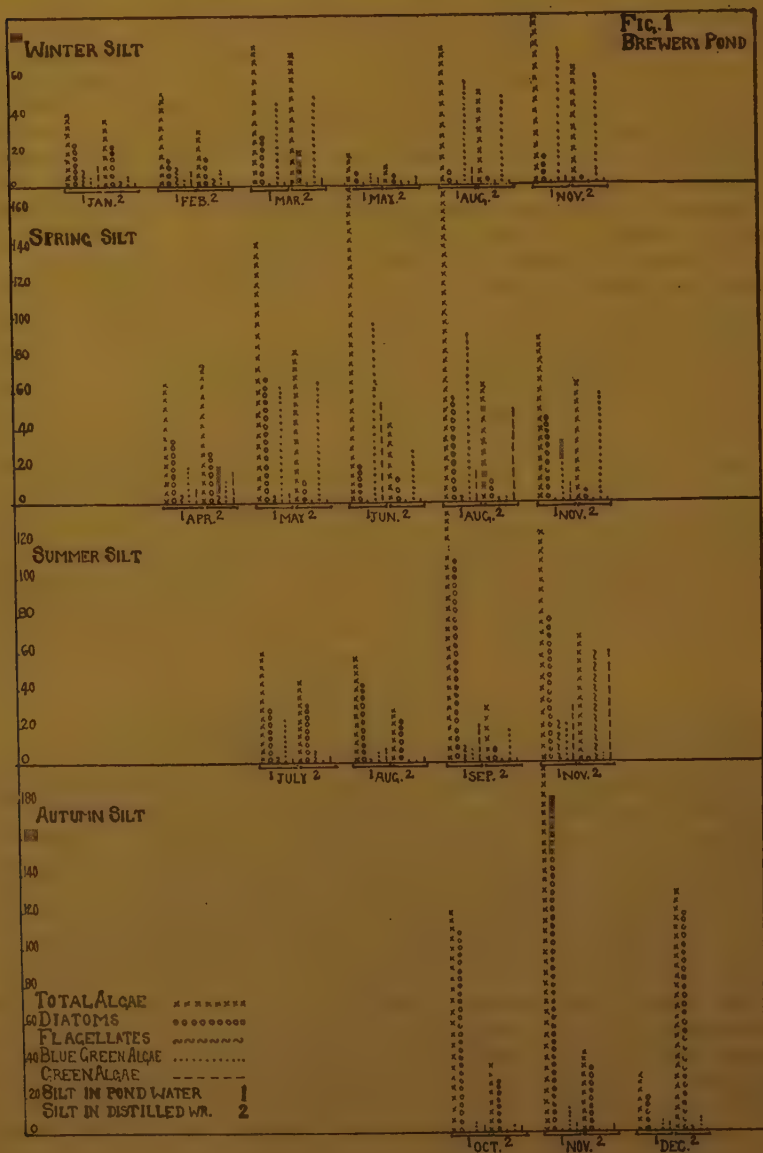
In the winter silt treated with pond water, *Chlamydomonas* spp. were abundant at the start; so also *Synedra tabulata* (including *Nitzschia palea*) and *Fragilaria capucina*, which remained fresh till March to appear in smaller numbers later. By March, *Oscillatoria terebriformis* appeared in a larger number and by August *Nostoc paludosum* and *Os. pseudogeminata* were conspicuous; by November these algæ were unhealthy. *Achnanthes affinis* and *Cocconeis placentula* were the frequent diatoms along with *Oscillatoria splendida* during November.

The winter silt in distilled water showed algæ more or less on lines indicated for silt in pond water but the flora was always poorer. Though more or less the same species were noticed in both, the number of individuals of each species was always more in pond water medium. In place of *Oscillatoria terebriformis*, however, noticed in pond water silt in March, *Os. splendida* was there in distilled water silt at that time.



*Spring silt* (collected at the beginning of April 1948)

In the spring silt treated with pond water, the algal estimates of May, June and August were the highest compared to those of winter and summer silts. The flora of autumn silt was no doubt more abundant than that of spring but was mainly composed of diatoms unlike the spring flora which was more varied (Fig. 1). The spring



silt estimates were higher because of *Navicula cryptocephala* and *Oscillatoria terebriformis* (peaks in May) and *Anabæna* sp. (peak in June). By August *Synedra tabulata* and *Nostoc paludosum* were abundant. Of the three spring months' totals again, the total of algæ noticed in June was the highest, because of an additional green alga, *Scenedesmus quadricauda*. Of the diatoms prominent in November, along with *Nostoc paludosum*, *Navicula cryptocephala* and *Synedra tabulata* stood foremost.

In the spring silt treated with distilled water also, the flora was more conspicuous than the flora in winter, summer and autumn silts (Fig. 1). This was on account of *Oscillatoria terebriformis* (May) and *Anabæna variabilis* forma (June). *Nostoc paludosum* and *Nostoc spongiæforme* were abundant in August and November respectively. *Navicula cryptocephala* and *Synedra tabulata* were no doubt frequent in April but they did not flourish thereafter. Even in spring, the flora of distilled water silt was poorer than that of pond water silt.

*Summer silt* (collected at the beginning of July 1948).

In the pond water summer silt the maximum dominance of algæ was noticed by September and this was due to *Synedra tabulata* and *Achnanthes affinis*. *Ankistrodesmus falcatus* and *Chlamydomonas* sp. too were present but in smaller numbers. The dominant diatoms by November were *Synedra tabulata* and *Achnanthes affinis*. *Cylindrospermum* sp. too was noticed at this stage.

Table I showing the pH variations of the two media on the silt of this pond shows a lowered pH by November in the case of "summer silt pond water medium". This lowered pH agreed with the appearance of a large number of *Chlamydomonas* spp. in November. This agreement threw some supporting light on the conclusions arrived at through field studies that abundance of *Chlamydomonas* and lowered pH could be associated.

The summer silt treated with distilled water showed a poorer flora again in comparison to that treated with pond water, just like the corresponding winter and spring silt. *Nostoc paludosum* was frequent in September and no other algæ appeared particularly conspicuous. But by November consistent with the lowered pH (see Table I) *Chlamydomonas* spp. became frequent just as in the summer silt treated with pond water.

*Autumn silt* (collected at the beginning of October 1948)

This silt treated with pond water showed a marked abundance of diatoms in October and November; *Achnanthes affinis* and *Cocconeis placentula* being the major ones. Excepting the sparsely present *Oscillatoria pseudogeminata* no other blue green algæ were frequent. In December the diatom total and the total algæ diminished.

The autumn silt in distilled water as usual was characterised by a smaller flora than that seen in pond water. In December, as an exception, *Achnanthes affinis* was noticed in rather large numbers and this accounts for the total of algæ being bigger than the corresponding total in pond water (Fig. 1—autumn silt).

TABLE I

*Silt of the Brewery Pond—pH Variations of the Medium*

			Jan.	Feb.	March	May	Aug.	Nov.
Winter silt :	P. W.	..	7.5	7.6	7.8	7.7	..	7.8
	D. W.	..	7.3	7.7	7.6	7.8	..	7.5
				April	May	June	Aug.	Nov.
Spring silt :	P. W.	..		7.7	8.0	7.0	..	7.2
	D. W.	..		7.7	7.9	7.0	..	6.5
					July	Aug.	Sept.	Nov.
Summer silt :	P. W.	..			6.4	..	..	5.5
	D. W.	..			5.9	..	..	5.1
						Oct.	Nov.	Dec.
Autumn silt :	P. W.	..				7.1	..	7.2
	D. W.	..				7.1	..	6.9

P. W. stands for Pond Water ; D. W. stands for Distilled Water.

(2) *Silt from the Lemna Pond*

The silt flora of this pond observed in the different seasons both in pond water and distilled water was always poorer than the flora of the Brewery pond silt (compare Figs. 1 and 2). But as noticed in the Brewery pond, more algæ were observed on the silt samples treated with pond water than on silt samples treated with distilled water considering all the four seasons.

*Winter silt* (collected at the beginning of January 1948)

In the winter silt treated with pond water, January counts were marked by *Cryptomonas ovata* and in March, *Euglena mutabilis* appeared in a large number. By May the bulk of algæ noticed was comprised of *Navicula pupula*, *Achnanthes linearis* and *Pinnularia subcapitata*, most of them however not being quite healthy. A large number of *Chlamydomonas* spp. and a few diatoms comprised the flora in November.

The winter silt treated with distilled water showed in January *Cryptomonas ovata* and *C. obovoides* and by March, an abundance of *Euglena mutabilis* was observed just like in pond water silt. The flora did not show any prominent changes later. Unlike in the pond-water silt, the diatoms in this silt did not significantly develop during the entire period of observation.

The pH of the "winter silt distilled water" had fallen from the January reading of 6.5 to 3.9 in November—*vide* Table II. The significant absence of algæ in the silt in November might be due to the very low pH. Lund (1942) reported a conspicuous fall in the algal flora in distilled water cultures (of bottom deposits of ponds) when the pH had fallen to 3.8.

TABLE II  
*Silt of the Lemna Pond—pH Variations of the Medium*

			Jan.	Feb.	March	May	Aug.	Nov.
Winter silt :	P. W.	..	5.1	5.4	4.1	4.4	..	5.9
	D. W.	..	6.5	6.2	4.2	4.0	..	3.9
				April	May	June	Aug.	Nov.
Spring silt :	P. W.	..		7.7	8.3	6.9	..	6.5
	D. W.	..		7.7	8.3	6.4	..	6.1
					July	Aug.	Sept.	Nov.
Summer silt :	P. W.	..			6.0	..	..	5.9
	D. W.	..			5.3	..	..	4.8
						Oct.	Nov.	Dec.
Autumn silt :	P. W.	..				4.6	..	4.7
	D. W.	..				4.8	..	3.6

P. W. stands for Pond Water ; D. W. stands for Distilled Water.

*Spring silt* (collected at the beginning of April 1948)

In the spring silt treated with pond water there was only an initial abundance of algæ and that was on account of *Navicula cryptocephala*, *Oscillatoria amphibia* and *Oscillatoria tenuis*. The only conspicuous alga in November was *Nostoc spongiæforme*.

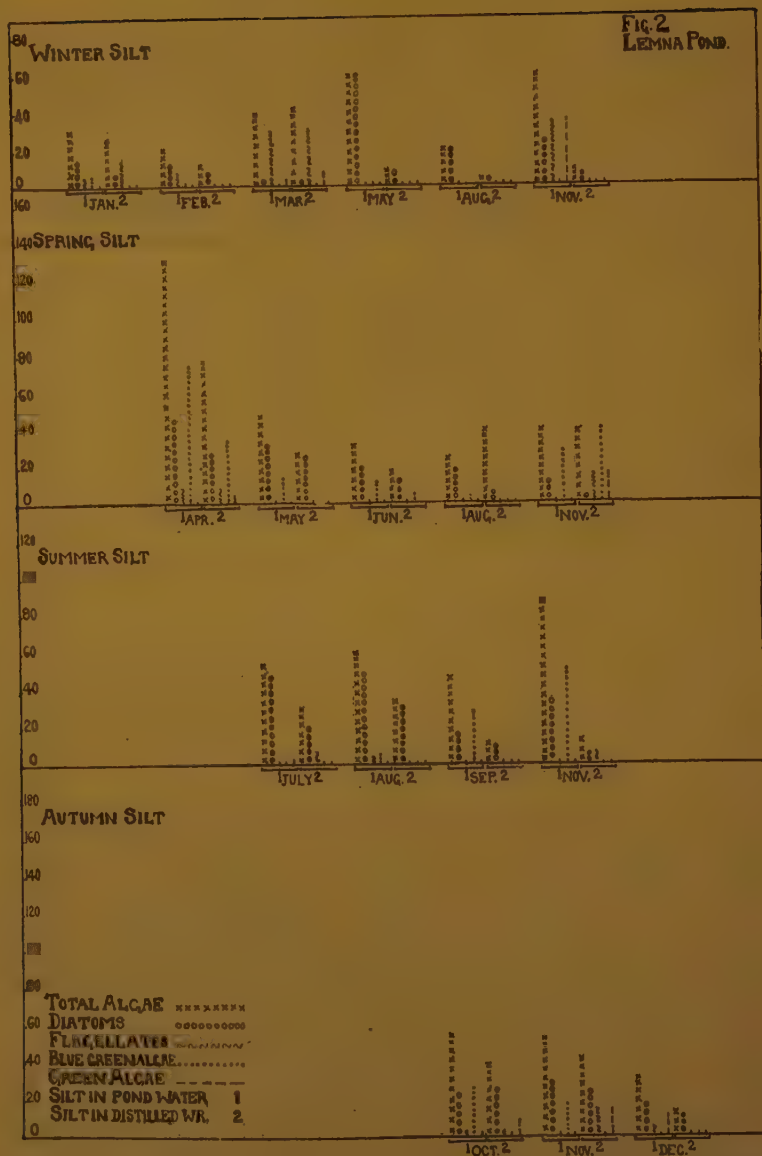
This applied also to the spring silt treated with distilled water, though the bulk of its flora was much smaller than that of pond water silt of spring; the dominant algæ in November were *Chlamydomonas* (palmelloid), *Anabæna oscillarioides* and *Oscillatoria pseudogeminata*.

The flora of spring silt, whether in pond water or distilled water, was richer than that of winter, summer and autumn silts (Fig. 2).

*Summer silt* (collected at the beginning of July 1948)

This in pond water showed an initial diatom abundance in July consisting of *Synedra tabulata*, *Achnanthes affinis* and *Navicula cryptocephala*. By August, *Gomphonema parvulum* was in large numbers.





The rise of numbers in September was caused by *Nostoc spongiaforme*. In November, in addition to *Navicula cryptocephala* and *Synedra tabulata*, the flora was characterised by *Nostoc spongiaforme*, *Oscillatoria terebriformis* and *Os. pseudogeminata*.

No noticeable changes were there in the "distilled water treated silt" except that *Chlamydomonas* (palmelloid) was frequent in November. Autumn silt (collected at the beginning of October 1948).

In pond water, this silt showed a flora comprised of some diatoms (e.g., *Synedra tabulata*, *Pinnularia mesolepta*, *Achnanthes affinis*) and some blue green algæ (e.g., *Nostoc spongiaforme*, vegetative *Anabæna* and *Oscillatoria pseudogeminata*). This flora became very poor by December.

The autumn silt in distilled water showed *Pinnularia mesolepta*, *Pinnularia subcapitata* and palmelloid *Chlamydomonas* though in small numbers. No members of Myxophyceæ were noticed throughout. By December the already low pH fell to 3.6—*vide* Table II—and as explained earlier, the absence of flora at this stage was understandable.

All the same, whenever the pH was low, algæ like *Microthamnion kutzingianum* and *Ophiocytium arbuscula* and *O. cochleare* appeared to flourish. Lund (1942) described the first alga as one favouring markedly acidic conditions. In the Lemna pond silt, when the pH was 3.6 in December, this alga was quite frequently observed.

It might be observed at this stage, by comparing Tables I and II, that the pH of the media on the Lemna pond silt was in general lower in all the seasons than the pH of media on the Brewery pond silt. The possible explanation for these lower values might be that the Lemna pond had been a typical stagnant sheet of water with a reducing bottom and characterised by active decay of organic matter. The summer silt of the Brewery pond had shown pH values lower than those observed in the other seasons, the factor of greater decay in warmer months being a probable cause.

#### SUMMARY

The algal flora noticed on the silt of the Lemna pond with a reducing bottom was in all seasons poorer than that of the Brewery pond which was regarded as having a normal (oxygen-rich) bottom.

The silt treated with pond water had shown a better growth of algæ in all the seasons concerned than the silt treated with distilled water, as seen in both the ponds.

As observed in both the ponds again, the silt collected in spring yielded a richer flora than the silts collected in winter, summer and autumn, though in the latter, obtained from the Brewery pond, diatoms were predominant.

Whenever the pH of the medium became low, a considerably diminished flora was observed.

The general succession of the different groups of algæ as noticed through field studies conducted on these ponds seemed to apply in a general way to the silt cultures also. Flagellates started the series in March, diatoms following by mid-spring, these in turn being followed by green algæ, blue-green algæ and some flagellates by summer. Finally autumn was characterised by diatoms.

The present study was undertaken mainly to find out whether algæ perennate on the pond bottom in any form thus accounting for the dominance at one time and the less frequent appearance or total

disappearance at other times but the results of the present study did not throw any light on the problem.

The algæ noticed in the silt cultures of both the ponds were the same as those observed in the field samples from near the surface of each pond, thereby suggesting that no special flora was confined to the silt as opposed to the general flora of the pond.

The writer is indebted to Professor F. W. Jane, Ph.D., D.Sc., for his guidance and criticism throughout the course of this work. He is also grateful to Professor W. H. Pearsall, D.Sc., F.R.S., for his interest in the work and for his helpful criticism.

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# STUDIES IN CROP PHYSIOLOGY

## Photosynthesis, Respiration and Pigment Content of Sugarcane Leaves in Relation to Age of Plant, Leaf Development and Nitrogen Deficiency

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(Received for publication on November 15, 1953)

### INTRODUCTION

EARLIER investigations showed that deficiency of nitrogen lowered the chlorophyll content of leaves (Singh, 1941; Lal, 1951). Nitrogen in doses below 33 per cent. of the total concentration of applied salts limited chlorophyll formation (Lal *et al.*, 1952). Its absence also caused normal leaf respiration at maturity (Lal *et al.*, 1951). Gregory and Richards (1929), Gregory and Baptiste (1936), and Gregory and Sen (1937) noted on the contrary, a subnormality in respiration of nitrogen-deficient barley leaves. It is intended in this paper to study the nitrogen deficiency effects in sugarcane leaves at various stages of the growth of the plant.

### EXPERIMENTATION

Sugarcane (Var. CoS. 109) was grown in sand nutrient cultures in Hoagland's complete nutrient and nitrogen-deficiency solutions as indicated in earlier paper (Lal and De, 1953 *a*). Samples of 6 leaves of various stages of development were taken at intervals of 45 days in the life-cycle. These leaves were picked up the previous evening and their rate of photosynthesis was determined on the following day under known conditions of light (500 watts Mazda lamp at a distance of 12 inches), temperature (30° C.) and CO<sub>2</sub> concentration (0.15 per cent.). Respiration of these leaves was also determined in darkness under otherwise similar conditions of temperature and CO<sub>2</sub>. The details of the method have been described in earlier papers from this laboratory (Singh and Lal, 1935). Concentrations of chlorophyll *a*, chlorophyll *b*, carotin and xanthophyll in the leaf extracts were determined after Loomis and Shull (1937) using Guthrie's standard. Recorded observations in these directions were calculated to a known leaf surface or weight and statistically examined to indicate the response of plant age, leaf development and nitrogen deficiency on these plant characters.

### EXPERIMENTAL FINDINGS

*Apparent Photosynthesis.*—Rate of apparent assimilation, in mgm. of CO<sub>2</sub> per 100 sq. cm. leaf surface per hour, varied widely with plant age, leaf development and nitrogen deficiency. In general, highest



rates were recorded at 90 days and gradually declined with advance in age (Tables I-III). Apparent photosynthesis was also high in the first leaf from apex but declined as the leaf surface expanded. Nitrogen deficiency lowered the apparent assimilation rate at 45, 90 and 180 days but failed to indicate any marked effect at 135 and 225 days in the life-cycle.

*Respiration.*—Respiration in mgm. of  $\text{CO}_2$  per 100 sq. cm. leaf area per hour showed the general tendency of high respiration during early stages and of low respiration at maturity. The decline with age was particularly evident beyond 135 days in complete nutrient plants and beyond 90 days under nitrogen deficiency. In fully manured plants, leaf respiration increased consistently from the first to the sixth leaf. Respiration of nitrogen-deficient leaves was highest in the second leaf from apex and showed a decline up to the fifth leaf. Nitrogen deficiency effects were more prominent in younger leaves where nitrogen deficiency showed tendency of higher respiration than the control. In the fourth to sixth leaves deficiency resulted in subnormality (Tables I-III).

TABLE I

*Effect of plant age on the photosynthesis, respiration and pigment content of sugarcane leaves*

(Over-all nutrition and leaf development values—Mean of 12)

	Age in days					S.D. at	
	45	90	135	180	225	1%	5%
Apparent photosynthesis ..	4.56	7.05	5.67	5.16	2.05	1.87	1.39
Real photosynthesis ..	7.42	10.18	8.35	7.16	3.20	2.30	1.71
Respiration ..	2.85	3.12	2.68	2.17	1.14	0.86	0.64
Chlorophyll <i>a</i> ..	5.77	8.22	6.02	3.24	1.21	1.45	1.08
Chlorophyll <i>b</i> ..	6.29	8.91	5.06	3.11	1.34	1.50	1.11
Carotin ..	4.90	9.07	6.89	5.43	3.01	1.42	1.05
Xanthophyll ..	7.15	10.28	10.95	7.59	3.48	1.43	1.06
Total green pigments ..	12.23	17.09	11.08	6.35	2.58	2.40	1.78
Total yellow pigments ..	12.05	21.01	17.84	13.02	6.49	2.56	1.91
Chlorophyll <i>a</i> /Chlorophyll <i>b</i>	0.96	0.92	1.27	1.11	0.94	0.34	0.25
Carotin ..	0.65	0.76	0.63	0.73	0.85	0.15	0.11
Total green/Total yellow ..	1.03	0.79	0.61	0.48	0.37	0.11	0.08

TABLE II

*Effect of leaf development on the rate of photosynthesis, respiration and pigment content of sugarcane leaves*

(Over-all nutrition and plant age values—Mean of 10)

	Leaf number from apex						S.D. at	
	1	2	3	4	5	6	1%	5%
Apparent photosynthesis ..	5.86	4.64	5.01	4.28	4.01	5.56	2.05	1.52
Real photosynthesis ..	8.03	7.07	7.39	6.68	6.09	8.28	2.52	1.87
Respiration ..	2.17	2.43	2.37	2.39	2.28	2.71	0.95	0.70
Chlorophyll <i>a</i> ..	3.93	5.13	4.96	5.13	5.77	4.47	1.59	1.18
Chlorophyll <i>b</i> ..	4.33	4.33	4.77	5.37	5.28	5.62	1.64	1.22
Carotin ..	4.83	5.77	6.11	6.29	6.01	6.13	1.56	1.16
Xanthophyll ..	7.06	7.74	7.81	9.23	9.07	8.43	1.57	1.17
Total green pigments ..	8.26	9.40	9.73	10.51	11.21	10.09	2.63	1.95
Total yellow pigments ..	11.89	13.51	13.91	15.52	15.09	14.56	2.81	2.09
Chlorophyll <i>a</i> /Chlorophyll <i>b</i> ..	0.97	1.21	1.13	0.93	1.16	0.83	0.38	0.28
Carotin/Xanthophyll ..	0.69	0.79	0.81	0.67	0.67	0.74	0.17	0.12
Total green/Total yellow ..	0.69	0.70	0.66	0.63	0.64	0.61	0.12	0.09

*Real Photosynthesis.*—Real photosynthesis was markedly reduced under nitrogen deficiency in all the successive leaves. Youngest leaf at the top and the sixth leaf from the apex showed highest rates when compared to leaves of intermediate insertion on the complete nutrient plants. Under nitrogen deficiency highest photosynthesis was recorded in the second leaf from apex. Real photosynthesis was also highest during early stages of growth and gradually declined towards maturity in both the cultures (Tables I-III).

*Chlorophyll a.*—The content of this pigment expressed in mgm. per 10 gm. fresh weight was highest in the leaf sampled at 90 days from fully manured plants and at 45 days in the samples from deficient cultures. In both, a gradual decline at later periods was evident. Nitrogen deficiency markedly reduced chlorophyll *a* between 90 and 180 days; and 45 and 225 days deficiency effects were less evident. Successive leaves from apex downwards also showed a fall in chlorophyll *a* content under nitrogen deficiency (Tables I-III\*).

\* Detailed tables from which the summarised results of Tables I-III were prepared, have not been given in text in view of space limitations.

TABLE III

*Effect of nutrition on the rate of photosynthesis, respiration and pigment content of sugarcane leaves*

(Over-all plant age and leaf development values—Mean of 30)

		Complete nutrition	Nitrogen deficiency	S.D. at	
				1 %	5 %
Apparent photosynthesis	..	8.48	4.32	1.19	0.88
Real photosynthesis	..	7.82	6.69	1.46	1.08
Respiration	..	2.41	2.38	0.55	0.41
Chlorophyll <i>a</i>	..	6.12	3.68	0.93	0.68
Chlorophyll <i>b</i>	..	5.93	3.96	0.95	0.71
Carotin	..	6.31	5.40	0.91	0.67
Xanthophyll	..	9.23	7.22	0.91	0.67
Total green pigments	..	12.09	7.64	1.52	1.13
Total yellow pigments	..	15.54	12.62	1.63	1.21
Chlorophyll <i>a</i> /Chlorophyll <i>b</i>	..	1.06	1.01	0.22	0.16
Carotin/Xanthophyll	..	0.70	0.76	0.09	0.07
Total green/Total yellow	..	0.72	0.59	0.07	0.05

*Chlorophyll b.*—Chlorophyll *b* content was highest at 90 days and fell with age in both the cultures. Nitrogen deficiency effects were less evident at 45 and 225 days. A marked reduction in chlorophyll *b* content between 90 and 180 days was noted in deficiency cultures. Nitrogen also reduced chlorophyll *b* content of successive leaves (Tables I-III).

*Carotin.*—Carotin content was highest at 90 days in sugarcane leaves and gradually declined with age irrespective of the nutritional conditions. At 90 and 135 days, nitrogen deficiency lowered carotin content but at later stages reductions were not so marked. With leaf development no marked variation in carotin was noted in either culture (Tables I-III).

*Xanthophyll.*—Xanthophyll content was also highest at 90 days and gradually declined towards maturity. Successive leaves from apex downwards were poorer in xanthophyll when nitrogen was withheld from the medium of growth. In complete nutrient plants xanthophyll content increased to a maximum in the fourth leaf and gradually declined in older leaves (Tables I-III).

Statistical analysis of the data showed the outstanding effect of nitrogen deficiency on apparent and real assimilation and the content of all the yellow and green pigments. Ratios between chlorophyll *a* and chlorophyll *b* and between carotin and xanthophyll were not significantly affected. The total green/total yellow pigment ratio, however, showed a marked response to conditions of nutrition. The effect of plant age on all the characters—respiration, photosynthesis, pigments and pigment ratios, was highly significant. Leaf age showed significant effect on total yellow pigments only. Interaction between plant age and nutrition was also significant on apparent assimilation, respiration, chlorophyll *a*, chlorophyll *b*, xanthophyll, total green and yellow pigments and the green/yellow ratio. Leaf age  $\times$  nutrition interaction, on the other hand, failed to indicate any significant response on any of the characters. These indicated beyond doubt that the effect of nitrogen deficiency varied characteristically with age of the plant and less so with the development of leaves and their position of insertion on the main shoot (Table IV).

### *Effect of Plant Age*

The over-all nitrogen deficiency and leaf development values showed a marked improvement in photosynthesis, respiration and pigment contents between 45 and 90 days and a significant fall at later stages. A higher rate of photosynthesis during early stages of the life-cycle

TABLE IV

*Effect of age, leaf development and nitrogen deficiency on the rate of respiration, photosynthesis and pigment content of sugarcane leaves*

#### Analysis of Variance

Due to	Degrees of Freedom	Mean sum of squares					
		Apparent assimilation	Real assimilation	Respiration	Chlorophyll <i>a</i>	Chlorophyll <i>b</i>	Carotin
Nutrition ..	1	20.10†	19.07†	0.01	89.18†	58.01†	12.37†
Plant age ..	4	40.64†	78.88†	7.30†	87.52†	101.95†	61.66†
Leaf age ..	5	5.24	6.75	0.33	4.00	3.01	2.81
Plant age $\times$ Nutrition	4	6.76*	7.82	2.12*	20.23†	10.52†	3.99
Leaf age $\times$ Nutrition ..	5	2.96	4.59	0.78	3.60	3.04	0.19
Error ..	40	2.79	4.23	0.60	1.71	1.80	1.62
Total ..	59	..	..	..	..	..	..
S.E./Observation ..	..	1.67	2.05	0.77	1.30	1.34	1.27



TABLE IV—(Continued)

Due to	Degrees of Freedom	Mean sum of squares					
		Xantho- phyll	Total green	Total yellow	Chl. <i>a</i> / Chl. <i>b</i>	Carotin/ Xantho- phyll	Green/ Yellow
Nutrition	1	60.80†	297.26†	128.19†	0.04	0.05	0.27†
Plant age	4	136.23†	374.00†	375.54†	0.26*	0.08*	0.81†
Leaf age	5	7.06	10.14	16.91*	0.22	0.04	0.01
Plant age × Nutrition	4	10.29†	55.77†	26.22†	0.10	0.01	0.06†
Leaf age × Nutrition	5	1.12	9.58	1.70	0.22	0.03	0.04
Error	40	1.64	4.67	5.28	0.10	0.02	0.01
Total	59	..	..	..	..	..	..
S.E./Observation	..	1.28	2.14	2.29	0.31	0.14	0.10

\* Significant effects at 5%.

† Significant effects at 1%.

was associated with a higher rate of respiration and high pigment content of the foliage and the decline in photosynthetic rate at later periods was accompanied by a fall in respiration and pigment content (Table I). Comparative data on other plant processes (Lal and De, 1953 *a, b, c, d*) showed that high photosynthetic efficiency of the leaves between 45–90 days was also correlated with the highest accumulation of mineral contents and highest relative growth rate of the plant. At this period of high physiological efficiency of the plant, marked accumulation of insoluble nitrogen compounds also took place but sugars failed to accumulate beyond a certain extent. Lack of accumulation of sugars during early stages when photosynthetic rate of the leaves was at its highest involved two possibilities. In the first instance, they were rapidly broken down during respiration to provide the necessary energy for the various building up processes in the plant. Secondly, sugars formed were directly utilized in the synthesis of various nitrogenous compounds so essentially required for the formation of new tissues during the period of highest relative growth rate of the sugarcane plant.

High respiration during early stages of 45–90 days appeared to be mainly due to high fructose and reducing sugars and high concentration of amide and insoluble nitrogen fractions of the leaf. No specific relationship between amino acid concentration and high rate of respiration was evident as recorded by Gregory and Sen (1937) in barley. It appeared therefore, that hexoses, amides and proteins played a more important part in maintaining high respiration rate of sugarcane leaves during early stages.

It was also significant to note that the period of high chlorophyll content coincided with the period of highest photosynthetic activity and high magnesium, nitrogen and protein content of leaves. A fall in chlorophyll content towards maturity was associated with a fall in these ingredients. It was thus evident that maximum development of chlorophyll pigments was possible only when the leaf contained sufficient quantities of the three principal ingredients, *viz.*, nitrogen, magnesium and proteins.

Another significant point was the predominance of chlorophyll *a* over chlorophyll *b* content of leaves during early stages of the life-cycle. A marked decline in chlorophyll *a*/chlorophyll *b* ratio towards the later stages was indicative of a greater fall in chlorophyll *a* relative to chlorophyll *b* at maturity. Similarly, a marked decline in green/yellow pigment ratio indicated the predominance of yellow pigments over the green as age advanced. Both these contributed materially to the low photosynthetic activity of the sugarcane leaves at later stage of the life-cycle (Table I).

#### *Effect of Leaf Development*

Over-all nutrition and plant age values showed that apparent and real assimilation rates were more or less similar in leaves of various stages of development. Respiration also showed insignificant differences with leaf development. Barring carotin and xanthophyll which were richer in older leaves none of the pigments showed any marked fluctuation (Table II).

An inter-comparison of these effects with those recorded in earlier papers (Lal and De, 1953 *a, b, c, d*) showed that failure to exhibit marked fluctuation in photosynthesis, respiration and pigment content with leaf development could largely be attributed to the insignificant variation in the contents of glucose, fructose, amides, 'rest' and insoluble nitrogen fractions in the developing leaves. Although there was higher content of sucrose in the older leaves the respiration of such leaves decreased markedly. This indicated the possibility that sucrose was not an important respirable material in the sugarcane plant. Similarly, the insignificant effects of leaf development on plant pigments could be attributed to the insignificant variations in the content of protein and magnesium in similar leaves.

#### *Effect of Nitrogen Deficiency*

Over-all plant age and leaf development values indicated beyond doubt that nitrogen deficiency significantly reduced apparent and real photosynthesis (*cf.* Singh, 1941; Lal, 1951). Respiration of sugarcane leaves, on the contrary, was more or less normal under nitrogen deficiency (Table III). It appeared therefore, that the average response of nitrogen deficiency was normal on respiration and subnormal on photosynthesis of the leaves of sugarcane. In contrast to this, barley leaves showed subnormal respiration (Gregory and Sen, 1937) and normal photosynthesis (Gregory and Baptiste, 1936) when nitrogen was withheld from the medium of growth.

Data recorded in sugarcane indicated that subnormal photosynthesis was related to a significant decline in pigment content of deficient leaves. All the individual pigments were affected. Marked reduction in total green, total yellow and green/yellow ratio was recorded. In short, a predominance of yellow over green pigments under nitrogen deficiency conditions was associated with subnormal photosynthesis of sugarcane leaves. Further, the normal respiration of these leaves was found to be mainly due to two distinct effects which were discernible in these leaves (i) an improvement in glucose, fructose and reducing sugars, and (ii) a reduction in amino acids, amides and proteins under nitrogen deficiency conditions. If both these groups of compounds were capable of being utilized as respirable substrate, nitrogen deficiency should exhibit two distinct effects: (a) subnormal respiration due to lesser nitrogenous compounds, and (b) supernormality due to greater concentration of hexoses. Both these effects appear to proceed side by side but the increases in hexoses amply compensated the effects of decreases in active nitrogenous compounds with the result that respiration remained more or less normal. Supernormality in leaf respiration during early stages (90 days) under nitrogen deficiency appeared to be largely associated with higher content of hexoses and other sugars in deficient leaves rather than any marked improvement in nitrogen fractions. The subnormality in respiration at 135 days appeared related to a lowering in the concentration of both active sugars and organic nitrogenous compounds. Under conditions of nitrogen deficiency, therefore, leaf respiration was supernormal at 90 days, subnormal at 135 days and more or less normal at maturity. Normal respiration of sugarcane leaves at maturity under nitrogen deficiency conditions was also recorded in an earlier contribution (Lal *et al.*, 1951). A comparison of these effects showed that under the conditions of nutrition tried in these investigations hexoses played a more vital part than nitrogen fractions in the respiration of sugarcane leaves.

#### SUMMARY

Under conditions of sand nutrient cultures a period of high photosynthesis, respiration and pigment content of sugarcane leaves was noted between 45 and 90 days. A significant fall in all these characters was observed between 180–225 days. High respiration during early stages was related to greater hexose, amide and protein content. Higher pigment concentration at this stage was largely due to high magnesium and protein content of leaves. A marked fluctuation in relative concentration of individual pigments was also recorded with a predominance of yellow over green pigments towards maturity.

With leaf development photosynthesis, respiration and pigment content showed no marked variation but carotenoids increased in older leaves. Nitrogen deficiency induced marked reduction in photosynthesis showing characteristic subnormal effects. Respiration was supernormal under similar conditions at 90 days and subnormal at 135 and 180 days with an average life-cycle value of respiration similar to that of the normal plants. In regulating respiratory activities of sugarcane leaves hexoses played a more vital part than the complex nitrogen compounds.

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# CONTRIBUTIONS TO THE EMBRYOLOGY OF STERCULIACEÆ—V

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THIS paper deals with the embryology of 10 species belonging to 4 tribes of Sterculiaceæ as listed below:

- Sterculiææ .. *Sterculia colorata* Roxb. and *S. fetida* L.  
Dombeyææ .. *Pentapetes phænicea* L., *Dombeya spectabilis* Bojer.  
                  and *D. mastersii* Hook.  
Buettneriææ .. *Abroma augusta* L., *Guazuma tomentosa* Kunth. and  
                  *Buettneria herbacea* Roxb.  
Helicterææ .. *Klienhowia hospita* L. and *Helicteres isora* L.

Observations on the seed structure of *Pterospermum heyneanum* are also included here. This is followed by a general discussion on the embryological characters of the family.

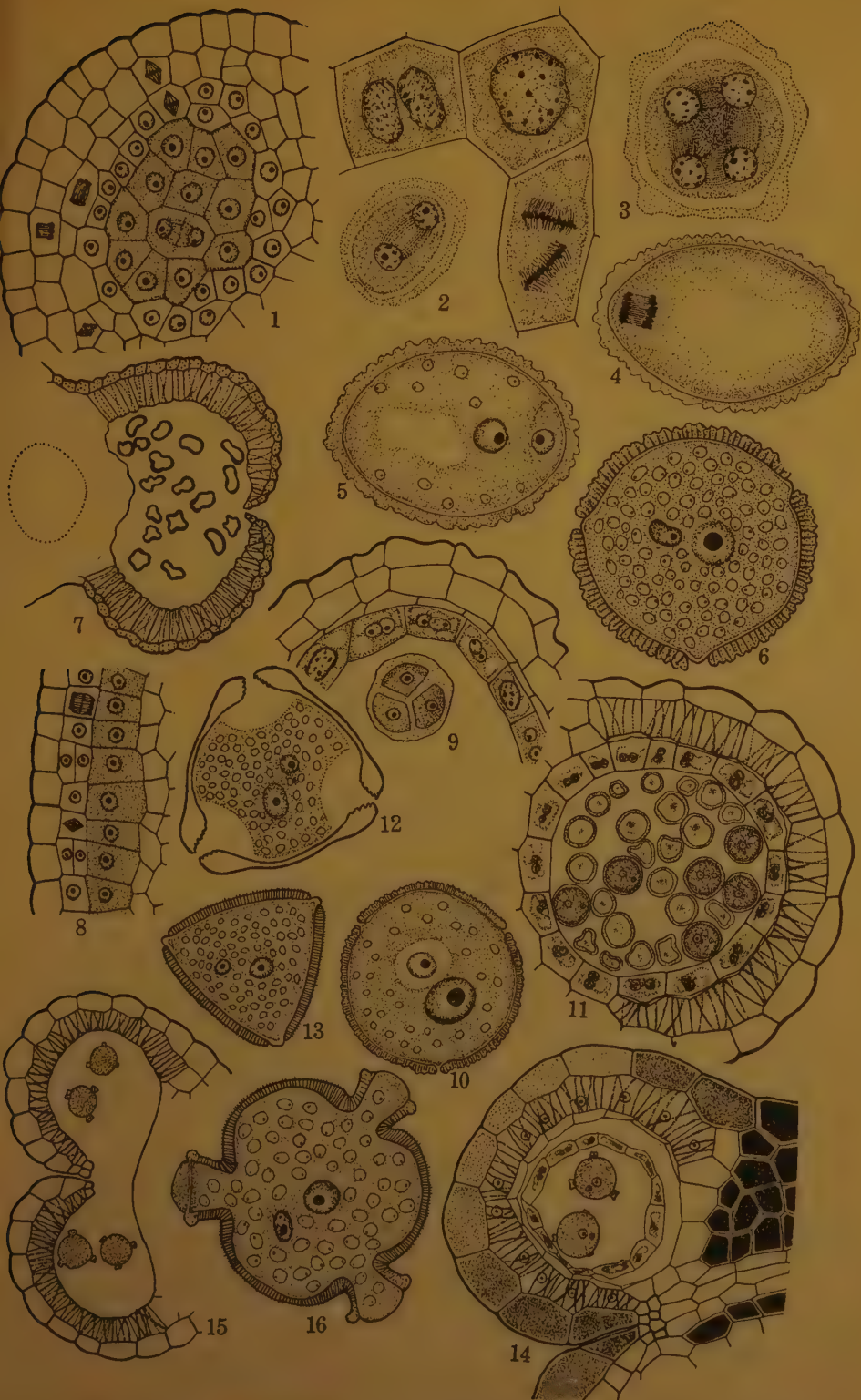
## MATERIALS AND METHODS

The material of *Dombeya spectabilis* was collected from P. R. College Gardens, Kakinada, and that of *D. mastersii* from the Fergusson College, Poona. The material of *Sterculia colorata* was kindly sent by Mr. C. S. Prakasa Rao from Banaras. Material of *Buettneria herbacea* was sent by Dr. K. Subrahmanyam from Bangalore and some of it was collected by the author from Anantagiri Hills. *Klienhowia hospita* and *Abroma augusta* were collected from Kakinada and a part of the material of the latter was also sent by Mr. R. Seshagiri Rao from the Indian Botanic Garden, Calcutta. The materials of the remaining species were obtained locally.

In all cases, formalin-acetic-alcohol was used as the fixative and the material was microtomed according to the customary methods. Delafield's and Heidenhain's Hæmatoxylin and Safranin and Fast Green were used as stains. Fast green, sometimes used as a counter-stain to Heidenhain's Hæmatoxylin, also gave good effect.

## SCALES AND HAIRS

In *Pterospermum*, the sepals and ovary wall are covered by brownish scales; in other genera there are several kinds of hairs (Figs. 37, 62, 96). The hairs on the ovary wall may be similar to those on the sepals as in *Guazuma tomentosa* (Figs. 105, 118), or they may be different as in *Helicteres isora* (Figs. 82, 83). The hairs on the ovary wall sometimes differ in shape in different species of the same genus, e.g., *Sterculia*



FIGS. 1-16. Microsporogenesis and development of pollen grains in Sterculiaceæ.

Figs. 1-7. *Sterculia fetida*.—Fig. 1. T.S. of an anther lobe showing divisions in sporogenous cells and parietal cells,  $\times 425$ . Fig. 2. Tapetal cells and a sporocyte in telophase I,  $\times 715$ . Fig. 3. Formation of a bilateral tetrad,  $\times 1065$ . Fig. 4. First division in microspore,  $\times 1065$ . Fig. 5. Young male gametophyte,  $\times 1065$ . Fig. 6. T.S. of mature pollen grain,  $\times 1065$ . Fig. 7. T.S. of an anther lobe of female flower,  $\times 135$ . Fig. 8. L.S. of part of an anther lobe of *Pentapetes phanicea*,  $\times 715$ . Figs. 9 and 10. *Abroma augusta*.—Fig. 9. T.S. of an anther lobe showing tapetum and a microspore tetrad,  $\times 425$ . Fig. 10. A two-celled pollen grain; note the cytoplasm of the generative cell,  $\times 715$ . Fig. 11. T.S. of an anther lobe of *Guazuma tomentosa* showing fibrous endothecium, tapetum and pollen grains; note the large proportion of degenerating pollen grains,  $\times 425$ . Fig. 12. A mature pollen grain of *Helicteres isora*,  $\times 1065$ . Fig. 13. A mature pollen grain of *Klienhowia hospita*,  $\times 1065$ . Figs. 14-16. *Buettneria herbacea*.—Fig. 14. T.S. of an anther lobe showing stomium, fibrous endothecium, degenerating tapetum and pollen grains,  $\times 285$ . Fig. 15. Dehiscent anther,  $\times 170$ . Fig. 16. Mature pollen grain,  $\times 1065$ .

(Figs. 24, 36) and are thus useful as diagnostic characters. In *Buettneria herbacea*, the hairs are slender and glandular on the young ovary (Fig. 106), but after fertilisation, they become large, stiff and spinescent. They develop mucilage sacs and are fed by strands arising from the vascular bundles of the ovary. They probably help in fruit dispersal (Fig. 105). In *Guazuma tomentosa*, the hairs are stellate and are subtended by glandular cells. After fertilisation, these groups of glandular cells grow out into tubercles which are especially conspicuous in the fruit.

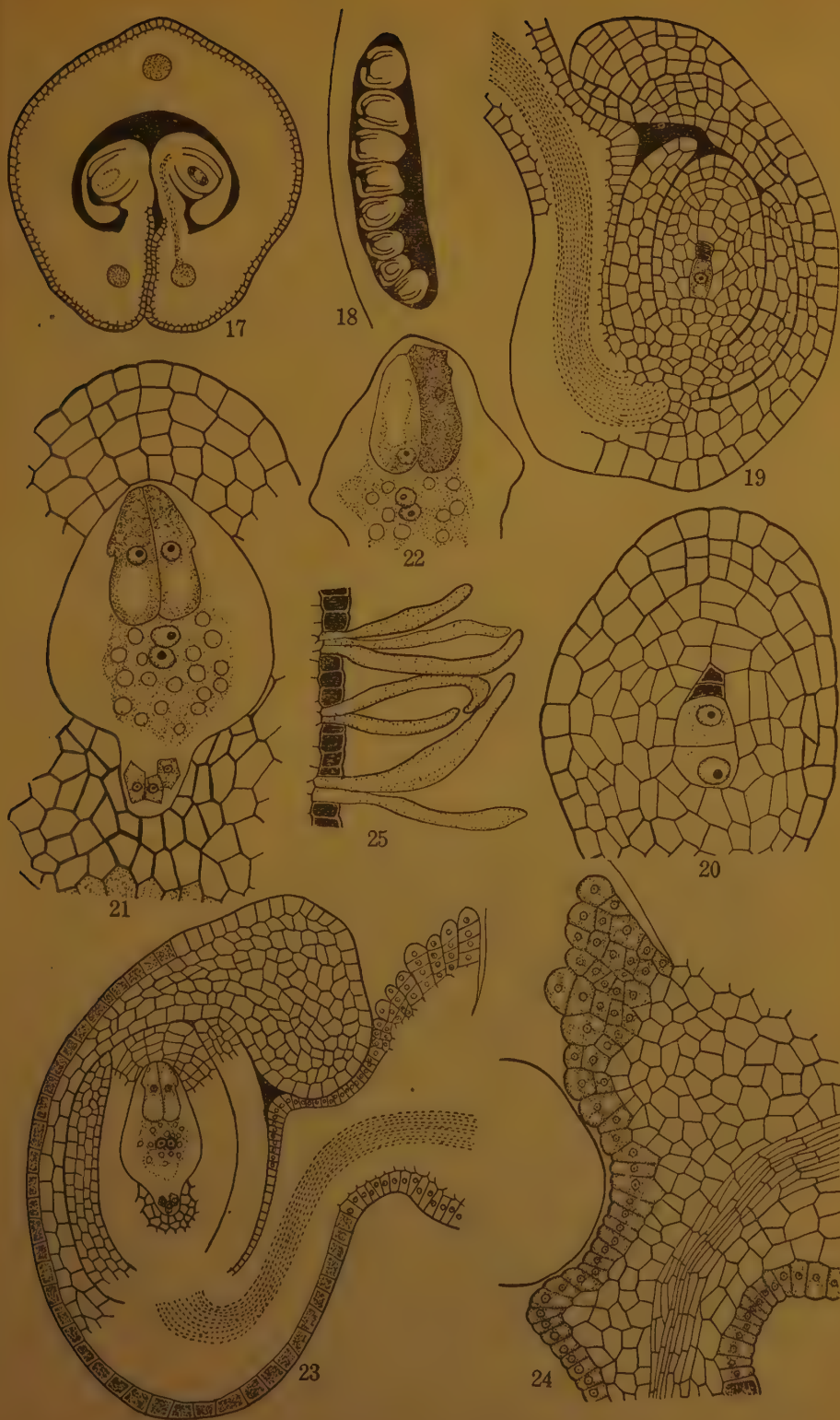
#### MICROSPOROGENESIS AND MALE GAMETOPHYTE

The anther wall including the epidermis is 4-5 cells thick. The epidermal layer consists of tangentially flattened tannin-bearing cells (Fig. 14). The hypodermal layer in all species, develops into the fibrous endothecium (Figs. 7, 11, 14, 15) and the innermost layer into the secretory type of tapetum. The cells of the tapetum are usually 2-nucleate but cells showing more than 2 nuclei or with a secondary uninucleate condition are also met with occasionally (Fig. 2). A well-defined stomium is organised in the anther wall (Figs. 7, 15).

The sporogenous cells show secondary increase in number and about 10-15 cells are seen in t.s. of an anther locus (Fig. 1). In *Sterculia* species, some of the chromosomes in telophase II lag behind. They fail to reach the poles in time and are left out without being incorporated in the daughter nuclei. They, however, perish without forming any micronuclei. In all species some abortive pollen grains occur along with the normal ones. Their percentage is quite high in *Guazuma tomentosa* (Fig. 11). In the female flowers of *Sterculia*, all the pollen grains in the anthers are distorted and sterile. The anther wall, however, shows a stomium and even an endothecium is differentiated (Fig. 7).

Cytokinesis occurs by furrowing. Microspore tetrads are usually tetrahedral (Fig. 9) and rarely bilateral (Fig. 3). In *Helicteres* and *Klienhowia*, the pollen grains are triangular and oblately flattened (Figs. 12, 13). In *Sterculia* species, they become ellipsoidal. The nucleus divides at one pole and forms a lenticular generative cell (Figs. 4, 5). After some time this cell migrates into the vegetative





FIGS. 17-25. *Sterculia foetida*.



Fig. 17. T.s. of a carpel,  $\times 45$ . Fig. 18. L.s. of carpel,  $\times 30$ . Fig. 19. L.s. of young ovule with the lowest megaspore of the linear tetrad enlarging,  $\times 200$ . Fig. 20. Nucellus with the two chalazal megaspores of the tetrad enlarging,  $\times 425$ . Fig. 21. Mature embryo-sac with socket of thick-walled cells around its chalazal end,  $\times 425$ . Fig. 22. Micropylar part of an embryo-sac which has been penetrated by a pollen tube,  $\times 425$ . Fig. 23. Mature ovule,  $\times 200$ . Fig. 24. Glandular cells of funicle of a mature ovule magnified,  $\times 335$ . Fig. 25. Hairs from ovary wall,  $\times 200$ .

cytoplasm, but its cytoplasm remains distinct as a hyaline sheath around the nucleus (Fig. 10). In the remaining genera, the pollen grains are spherical. In *Pentapetes* and *Dombeya* (Dombeyæ), the exine is spine-scent, while in the rest it is smooth. In all cases, the pollen grains are triporate and 2-nucleate at the time of shedding. In *Buettneria herbacea*, the germ pores are raised on papillate projections of the exine (Fig. 16). Starch grains are found abundantly in the cytoplasm of the mature pollen grains.

#### OVULE

The ovules which arise as papillæ on the inner wall of the carpels (Figs. 50, 86), closely fill the loculus in *Pentapetes phanicea*, *Klienhowia hospita* (Fig. 67), *Buettneria herbacea* (Fig. 97) and *Guazuma tomentosa* (Figs. 106, 107), while in *Sterculia* species (Figs. 17, 28) and *Helicteres isora* (Fig. 73), they are not so crowded. In all species, they are anatropous with ventral raphe, bitegmic and crassinucellate. In *Sterculia fætida* (Fig. 18), *Helicteres isora* (Fig. 74), *Pentapetes phanicea* (Fig. 38), *Guazuma tomentosa* (Fig. 108) and *Abroma augusta*, the micropyles face the floral axis, while in the rest they are turned towards the top of the loculus. In *Dombeya*, *Klienhowia*, *Abroma* and *Pentapetes*, there is a blunt chalazal outgrowth due to which the ovules appear top-shaped (Figs. 47, 71).

As in other Malvales, the inner integument is more massive and tardy in growth than the outer (Figs. 19, 34, 42, 54, 69, 90). The cells of the outer epidermis of the outer integument and the inner epidermis of the inner integument accumulate tannin (Figs. 23, 54, 71, 80, 100). The micropyle varies in structure in the different species. In *Pentapetes phanicea* (Fig. 47), *Dombeya* species (Figs. 60, 68) and *Klienhowia hospita* (Fig. 71), the micropyle is zigzag and is formed by both the integuments. In *Sterculia* species (Figs. 23, 35), the pore formed by the inner integument is wider than that formed by the outer. In *Abroma augusta*, the micropyle is formed only by the outer integument. The nucellus of the fertilisable ovule protrudes beyond the inner integument (Fig. 91) so that the description of Banerji (1941) that both the integuments take part in the formation of the micropyle is applicable only to the post-fertilisation stages. In *Guazuma tomentosa*, the micropyle is formed only by the outer integument; the inner covers only about  $\frac{2}{3}$  of the nucellus (Figs. 115, 119). In *Buettneria herbacea*, the inner integument grows only to about half the height of the nucellus. The outer integument is developed only on the side opposite to the funicle and stands as high as the nucellus in the upper tier of ovules, but grows much less in the lower ovules (Figs. 100, 102). In the former, the nucellus presses against a hairy placental obturator. In *Helicteres*



FIGS. 26-37. *Sterculia colorata*.

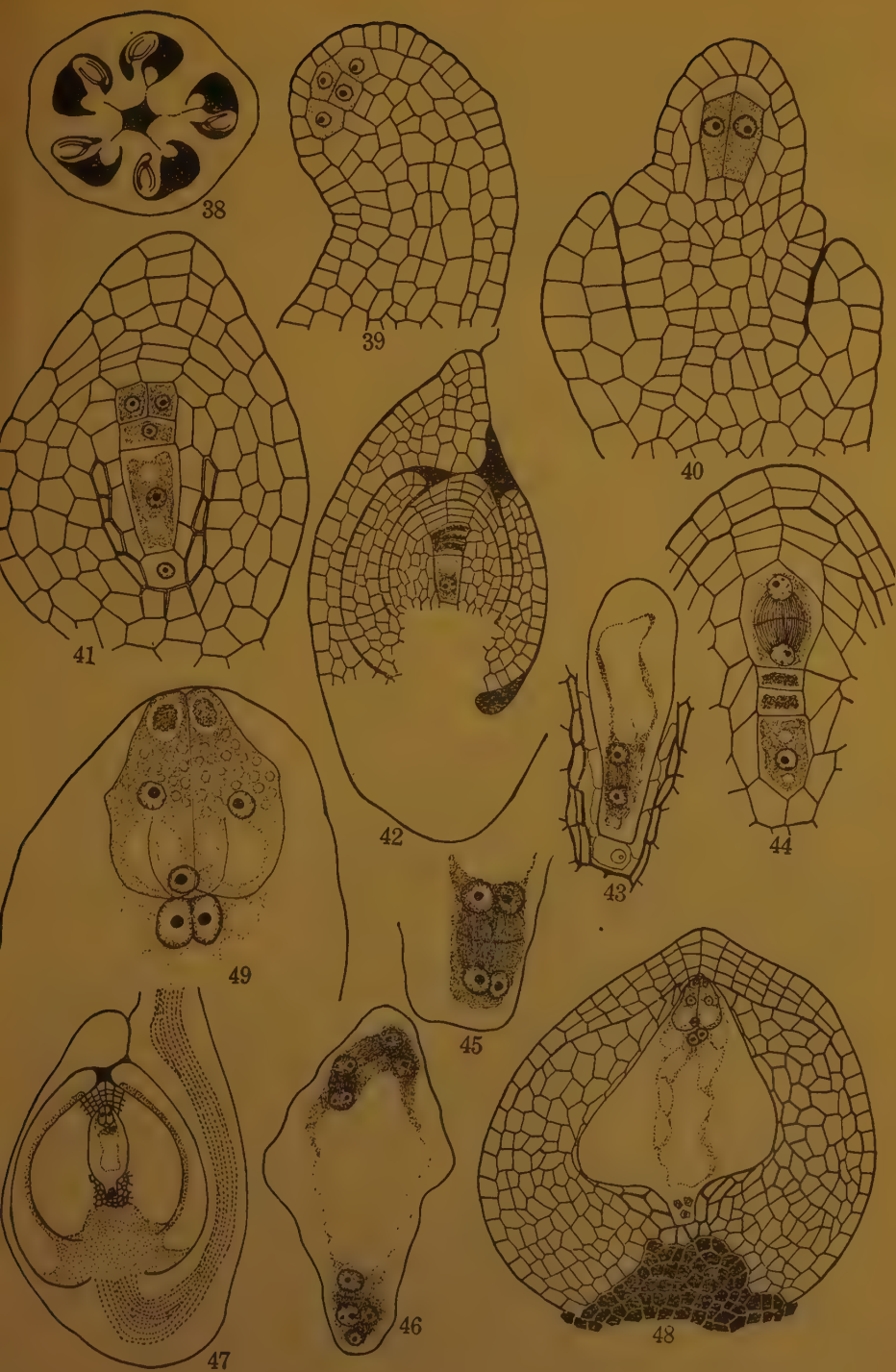
Figs. 26 and 27. L.s. and T.s. of carpel,  $\times 35$ . Fig. 28. Young ovule showing multicellular archesporium,  $\times 355$ . Fig. 29. Ovule showing formation of parietal tissue,  $\times 425$ . Fig. 30. Ovule with two functional megaspore mother cells,  $\times 425$ . Fig. 31. Nucellus showing dyads, parietal tissue and epidermal cap,  $\times 500$ . Fig. 32. Linear tetrad with the third megaspore from the micropylar end enlarging,  $\times 500$ . Fig. 33. First free nuclear division in the functional megaspore,  $\times 500$ . Fig. 34. Ovule with 2-nucleate embryo-sac,  $\times 185$ . Fig. 35. Ovule with mature embryo-sac,  $\times 135$ . Fig. 36. Carpel showing two ovules with degenerating embryo-sacs,  $\times 45$ . Fig. 37. Glandular hairs from the ovary wall,  $\times 200$ .

*isora*, the growth of the integuments ceases practically after the tetrad stage of the ovule and both the integuments cover less than half of the nucellus at the time of fertilisation (Figs. 78, 80). After fertilisation, however, in this species also, a zigzag micropyle is formed as in other species (Fig. 82).

The nucellus is massive and varies from spherical to fusiform shape (Figs. 48, 70, 80, 100, 101). In all species, there is an epidermal cap which ranges in thickness from 2-3 layers in *Guazuma* (Fig. 16) to 5-6 layers in *Dombeya* species (Figs. 59, 65). In several species, e.g., *Dombeya spectabilis* (Fig. 54), *Abroma augusta* (Fig. 89), *Guazuma tomentosa* (Fig. 109), etc., the megaspore mother cell extends to the chalaza. During further growth, several layers of cells are added to the nucellus below the embryo-sac (Figs. 23, 35, 48, 59, 70, 92, 100, 119). In *Pentapetes phanicea*, the layer of cells immediately surrounding the developing embryo-sac seems to be tapetal in function since the cells are richly protoplasmic. It gets crushed early (Figs. 41, 43). In all species, the cells of the nucellus around the lower half of the embryo-sac become thick-walled so that the embryo-sac in this region is unable to expand and remains much narrower than the micropylar part. These cells surrounding the chalazal end of the embryo-sac also become lignified in *Helicteres isora*. In all species they lose their protoplasmic contents, accumulate tannin and stain deeply. Starch grains also appear in them after fertilisation (Fig. 130). In *Abroma augusta*, the socket of thick-walled cells projects into the embryo-sac as a postament in the developing seed (Fig. 129). While the growth of the embryo-sac keeps pace with the growth of the developing seed in most species, in *Helicteres isora*, the embryo-sac practically remains of the same size after fertilisation (since it is invested by lignified cells), while the nucellus grows comparatively vigorously in the lower region. A hypostase is differentiated in this species and serves to connect the vascular bundle in the funicle with the embryo-sac, thus facilitating rapid transport of food materials (Fig. 82).

#### MEGASPOROGENESIS AND EMBRYO-SAC

The primary archesporium in the ovule consists of a group of cells (Figs. 28, 39, 51, 75, 87), but usually only one axially placed hypodermal cell functions and the rest merge into the nucellus (Figs. 29, 52, 54, 63, 68, 76, 89, 109). Occasionally, two collaterally placed cells were seen to function till the megaspore mother cell stage (Figs. 30, 40, 55, 88). In one ovule of *Dombeya spectabilis*, two 2-nucleate embryo-sacs were noticed (Fig. 58). In this species, sometimes two superposed archesporial cells were seen to function. The upper cell



FIGS. 38-49. *Pentapetes phænicea*.

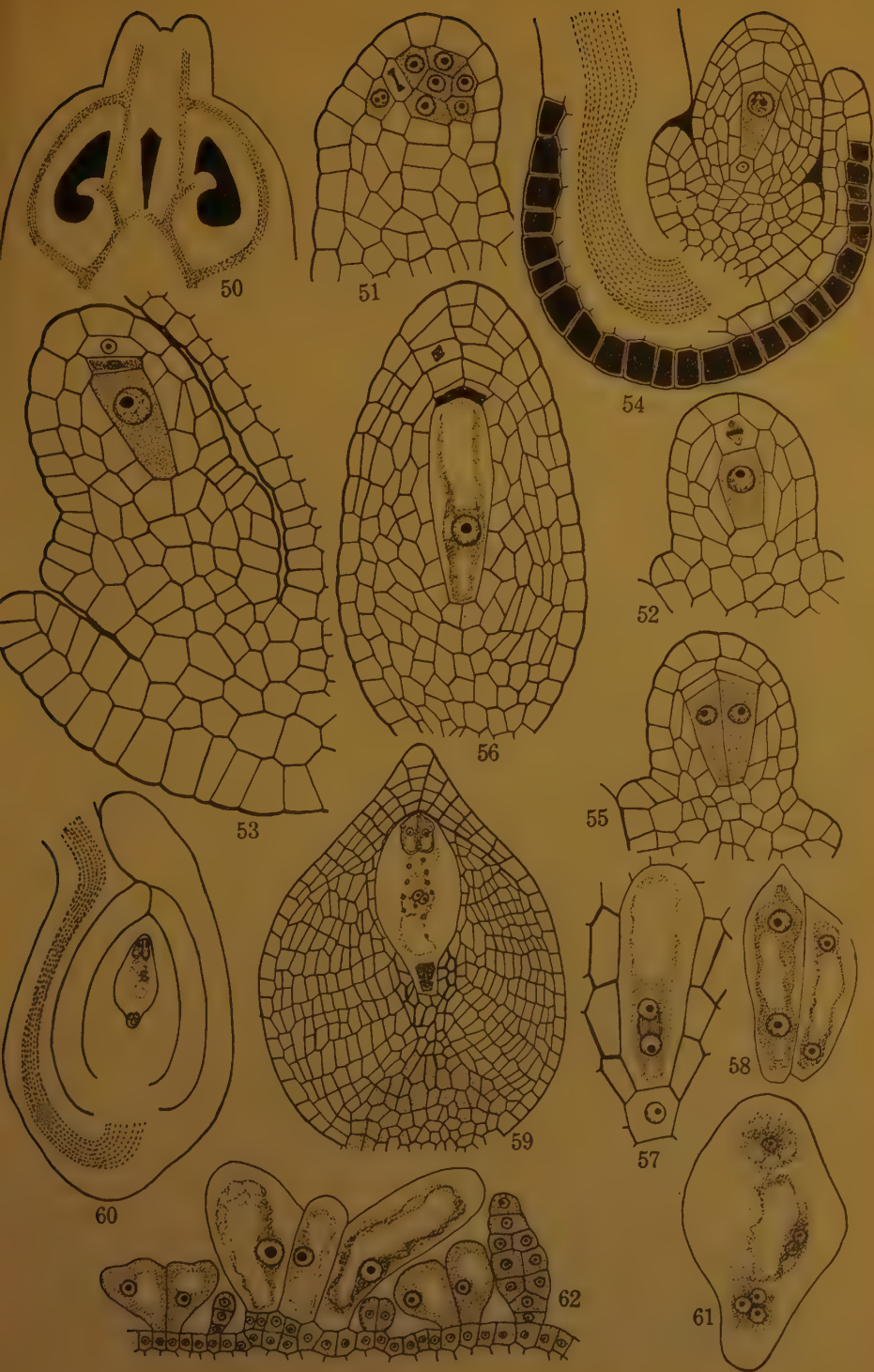


Fig. 38. T.s. ovary,  $\times 15$ . Fig. 39. Ovule primordium showing multicellular archesporium,  $\times 425$ . Fig. 40. Ovule with two functional megaspore mother cells,  $\times 425$ . Fig. 41. Nucellus with T-shaped tetrad,  $\times 425$ . Fig. 42. Ovule with linear tetrad of which the lowest megaspore is enlarging,  $\times 200$ . Fig. 43. First free nuclear division in embryo-sac; note the tapetal layer of cells around the enlarging embryo-sac and the thick-walled cells,  $\times 425$ . Fig. 44. A linear tetrad with both the terminal megaspores forming embryo-sacs,  $\times 425$ . Figs. 45 and 46. Nuclear divisions in the embryo-sac; note the secondary spindle fibres and cell plates,  $\times 425$ . Fig. 47. L.s. fertilisable ovule,  $\times 90$ . Fig. 48. Nucellus of fertilisable ovule with nucellar cap embryo-sac, zone of thick-walled cells around its lower end and the tannin-bearing cells,  $\times 335$ . Fig. 49. Upper part of the embryo-sac showing the egg apparatus and polar nuclei; note the starch grains and ring-like patches in synergids,  $\times 715$ .

in such cases cuts off the primary parietal cell and then gets crushed by the lower which functions directly as the megaspore mother-cell (Fig. 53). Such an archesporium appears as a very much reduced form of the one seen in *Pterospermum* species (C. V. Rao, 1949, 1952).

After cutting off the primary parietal cell to the outside, the megaspore mother cell grows for some time and undergoes the two meiotic divisions which usually result in a linear tetrad of megaspores (Figs. 20, 31-33, 42, 69, 78, 90, 99, 110, 111, 113, 114) and occasionally T-shaped tetrad (Figs. 41, 64, 112). The lowest megaspore of the tetrad functions and gives rise to the embryo-sac according to the *Normal*-type. In one case, the second megaspore from the micropylar end in *Guazuma* (Fig. 114) and in another the third in *Sterculia colorata* (Fig. 32), were seen to be enlarging, while others were showing signs of degeneration. In one ovule of *Sterculia foetida* (Fig. 20), the two chalazal megaspores of a tetrad were enlarging. Figure 44 shows a megaspore tetrad of *Pentapetes phanicea* in which the micropylar and chalazal megaspores are forming the embryo-sacs while the median ones are degenerating. The chalazal megaspore has formed a 1-nucleate embryo-sac, while the micropylar one which is more precocious, is showing the first free nuclear division. On the spindle can be seen an evanescent cell plate. In this species such cell plates are noticed in the telophase of the second and third divisions (Figs. 45, 46). Nuclei placed close together get connected by secondary spindle fibres.

The embryo-sac presents normal features. The synergids are hooked (Fig. 79). In *Pentapetes phanicea* starch grains are present in the cytoplasm of the synergids (Fig. 49). In *Pentapetes phanicea* (Fig. 49) and *Abroma augusta* (Fig. 92), each synergid shows near its micropylar end, an oval or rounded deep-staining patch with frilled rim. This is probably analogous to the filiform apparatus. A similar structure has been noticed in the synergids of *Pachira rosea* of Bombacaceæ (C. V. Rao, 1954). In *Buettneria herbacea*, in one ovule, one of the synergids showed egg-like vacuolation (Fig. 103). The polar nuclei do not fuse till the time of fertilisation (Fig. 22). The antipodals are 3 in number, 1-nucleate and ephemeral. Starch is seen in the embryo-sac. It is especially abundant in *Klienhowia hospita* in which the nucellar cells also store it (Figs. 69, 70). A case of an embryo-sac with reversed polarity was noticed in *Helicteres isora*; this has been described elsewhere (C. V. Rao, 1952 a).



FIGS. 50-62. *Dombeya spectabilis*.

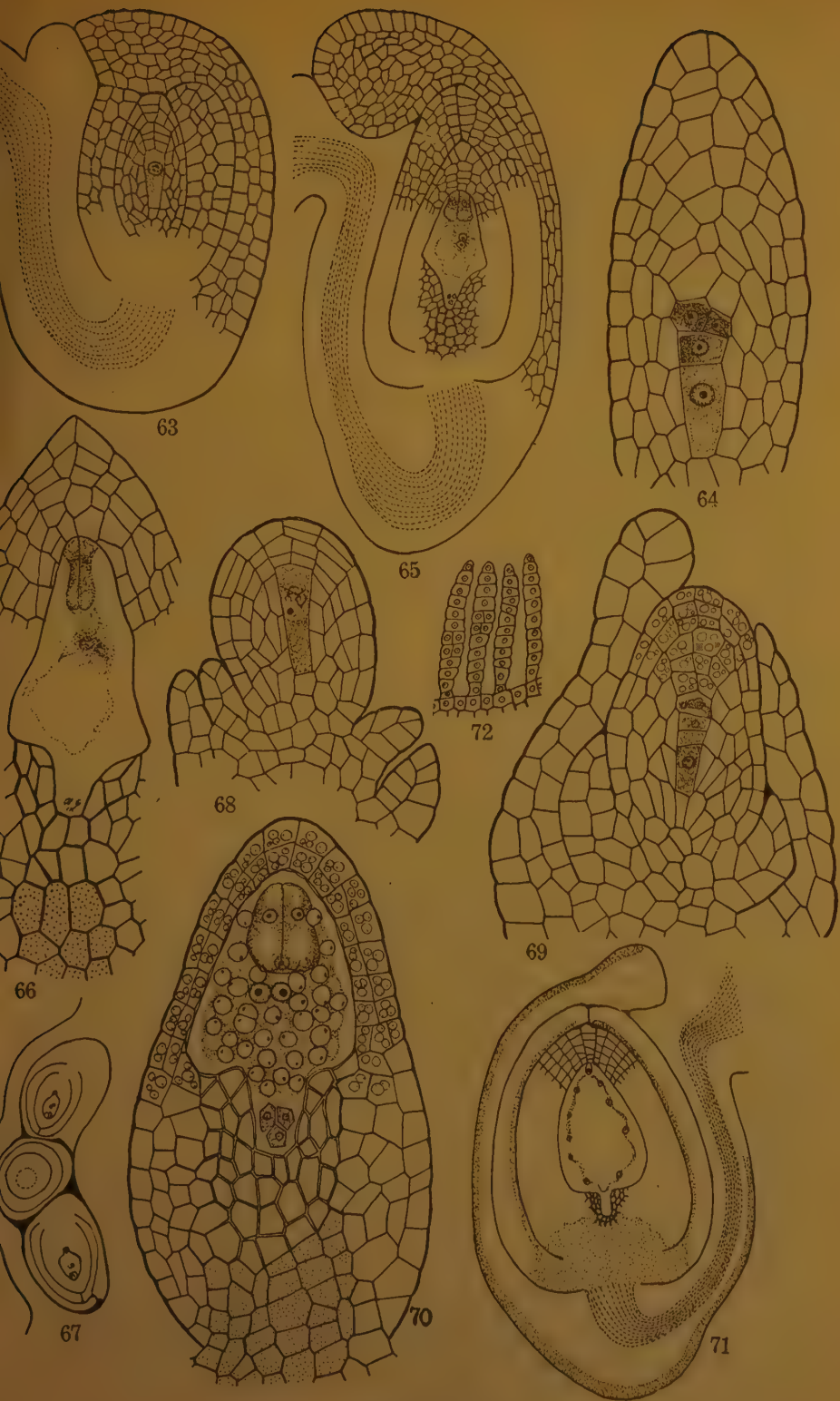
Fig. 50. L.s. ovary showing ovule primordia,  $\times 45$ . Fig. 51. Ovule primordium with multicellular archesporium; note the degenerating cell,  $\times 425$ . Fig. 52. First division of primary parietal cell,  $\times 425$ . Fig. 53. Ovule showing development of integuments and parietal layers,  $\times 425$ . Fig. 54. Ovule with two superposed megaspore mother cells of which the upper is degenerating,  $\times 715$ . Fig. 55. Ovule with two megaspore mother cells,  $\times 425$ . Fig. 56. Nucellus with enlarging functional megaspore,  $\times 425$ . Fig. 57. First free nuclear division in functional megaspore,  $\times 1065$ . Fig. 58. Two 2-nucleate embryo-sacs in one ovule,  $\times 715$ . Fig. 59. Nucellus of fertilisable ovule showing nucellar cap, embryo-sac, thick-walled cells around it and the tannin-bearing cells in the chalaza,  $\times 200$ . Fig. 61. A degenerating embryo-sac,  $\times 285$ . Fig. 62. Glandular hairs from the ovary wall,  $\times 200$ .

#### FERTILISATION

In *Pentapetes phænicea*, *Buettneria herbacea* and *Abroma augusta* the style shows a styler canal which is lined by narrow elongated and richly protoplasmic cells. In *Abroma*, it is occluded at the base of the style by large radially elongated cells (Fig. 122). The axial space of the ovary is also lined by richly protoplasmic cells. In this species, these cells grow out into elongated hairs after fertilisation (Figs. 93, 95). In *Pentapetes phænicea*, in which the ovules have short funicles, the micropyles stand close to or almost in contact with the placenta. In others, there are various contrivances which facilitate the progress of pollen tubes towards the micropyles. In *Sterculia foetida* and *Abroma augusta* in which the funicles are pretty long, the latter are lined by radially elongated glandular cells (Figs. 23, 24, 91, 94). In *Abroma*, these cells also contain starch grains and seem to be well adapted to nourish the pollen tubes which pass along them towards the micropyles. In *Helicteres isora*, the naked nucellus lies in contact with some glandular cells of the placenta (Fig. 80). In *Buettneria herbacea*, the upper ovules have their nucelli in contact with a hairy placental obturator (Fig. 100). The lower ones have no such contrivance and their nucelli lie wedged in between the loculus and the chalaza of the upper ovules (Fig. 101). It is probably due to this difference that the upper ovules as a rule develop into seeds, while the lower ones abort (Figs. 103, 106).

In *Abroma augusta*, the pollen grains germinate in the stigmatic furrows (Fig. 122). Though there is a well marked styler canal, the pollen tubes penetrate through the tissue of the style and enter the axial space of the ovary. Creeping along the funicles they enter the ovules in a porogamous manner. They penetrate the nucellar cap and enter a synergid (Figs. 81, 122, 123) or pass by it and destroy it (Fig. 101). In *Helicteres isora* and *Klienhowia hospita* the track made by the pollen tube in the nucellus can be seen for a long time in the developing seed, although the pollen tube itself perishes quite early (Figs. 82, 157). The tube nucleus seems to degenerate inside the pollen tube itself. One male nucleus fuses with a polar nucleus first (Fig. 124) and then the triploid primary endosperm nucleus is formed. The process of syngamy is very much slower. By the time it is completed, some endosperm nuclei are already formed (Figs. 132, 157, 173). In *Klienhowia*, *Pentapetes* and *Abroma* both the ovule and embryo-sac grow considerably after fertilisation. The starch reserve of the embryo-sac appears to be completely used up during this process, but accumulations of starch grains are seen in the chalaza and integuments.





FIGS. 63-72.



Figs. 63–66. *Dombeya mastersii*. Fig. 63. Ovule with full grown megaspore mother cell,  $\times 200$ . Fig. 64. Nucellus with a T-shaped tetrad of megaspores,  $\times 425$ . Fig. 65. L.s. fertilisable ovule,  $\times 170$ . Fig. 66. Nucellus showing a degenerating embryo-sac,  $\times 355$ . Figs. 67–72. *Klienhowia hospita*. Fig. 67. L.s. loculus of ovary,  $\times 75$ . Fig. 68. Ovule with full-grown megaspore mother cell,  $\times 425$ . Fig. 69. Ovule with linear tetrad; note the starch grains in cells of the parietal tissue,  $\times 425$ . Fig. 70. Nucellus of mature ovule showing nucellar cap, embryo-sac and zone of thick-walled cells; note the large starch grains in the cytoplasm of the embryo-sac,  $\times 425$ . Fig. 71. Young seed with a few endosperm nuclei,  $\times 330$ . Fig. 72. Hairs from sepals,  $\times 200$ .

### ENDOSPERM

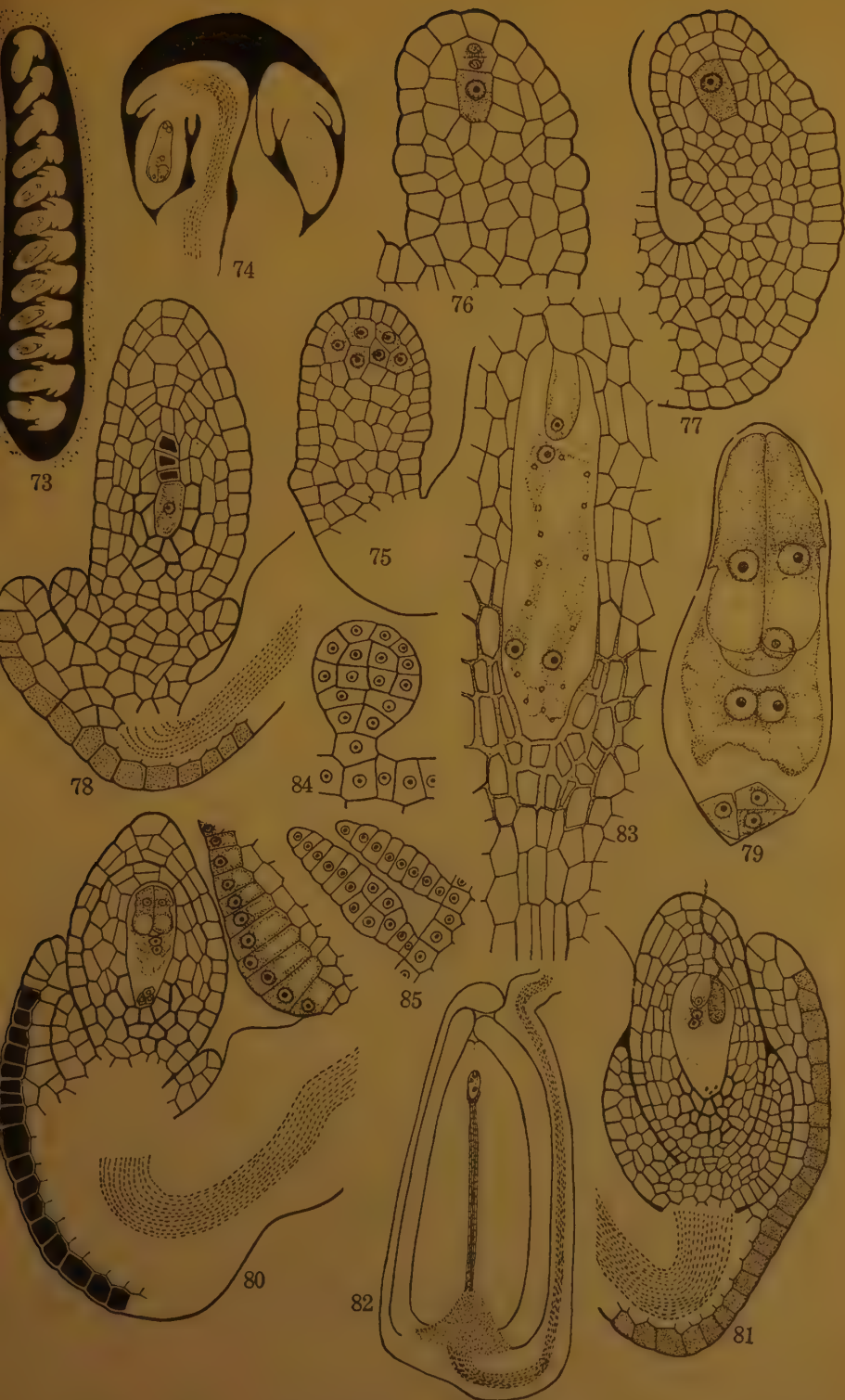
The endosperm is formed according to the nuclear type. It shows both micropylar and antipodal aggregations in which the nuclei are more closely crowded. In the tubular antipodal end of the embryo-sac, the nuclei often fuse together to form large polyploid nuclei. The nucleus situated right at the antipodal end of the embryo-sac is especially conspicuous by its size and number of nucleoli. In *Abroma* and *Pentapetes*, while the normal nuclei measure  $8\text{--}10\mu$  in diameter, the gigantic endosperm nuclei at the antipodal end of the sac measure  $30\text{--}40\mu$ . In *Pentapetes phænicea*, these polyploid nuclei are seen to divide, forming large mitotic figures (Fig. 128). Nuclear fusions are not noticed in the micropylar part of the endosperm.

The endosperm becomes cellular at a relatively late stage in seed development. By this time more than a hundred endosperm nuclei are already formed and the embryo shows cotyledon primordia. The cell formation occurs by the process of cleavage or indentation (Figs. 125, 126). First the protoplasm around the nuclei becomes vacuolated. The zones of contact between the protoplasts are now marked by regions of denser cytoplasm and shortly afterwards cleavage furrows develop along them and the protoplasts become separated. Cell walls are secreted later. Cell formation occurs simultaneously in the micropylar and antipodal regions in *Abroma augusta*. At first the cells in the antipodal region are larger than those in the micropylar part. The former contain one large polyploid or 2–3 triploid nuclei. By further divisions they become smaller and uninucleate. After the endosperm in this region has become cellular, the gigantic nucleus begins to degenerate. It becomes more and more chromatic and develops a central vacuole. Finally it collapses and disappears. The endosperm completely crushes the nucellus so that there is no perisperm in the mature seed.

In all species, the endosperm formation commences soon after fertilisation. In *Helicteres isora*, on the other hand, it is suspended after 3–4 endosperm nuclei are formed and during this period the seed grows considerably.

### EMBRYO

The development of the embryo and seed have been studied in *Abroma augusta* (Figs. 132–156), *Klienhowia hospita* (Figs. 157–172) and *Pentapetes phænicea* (Figs. 173–189) and seed development alone



FIGS. 73-85. *Helicteres isora*.

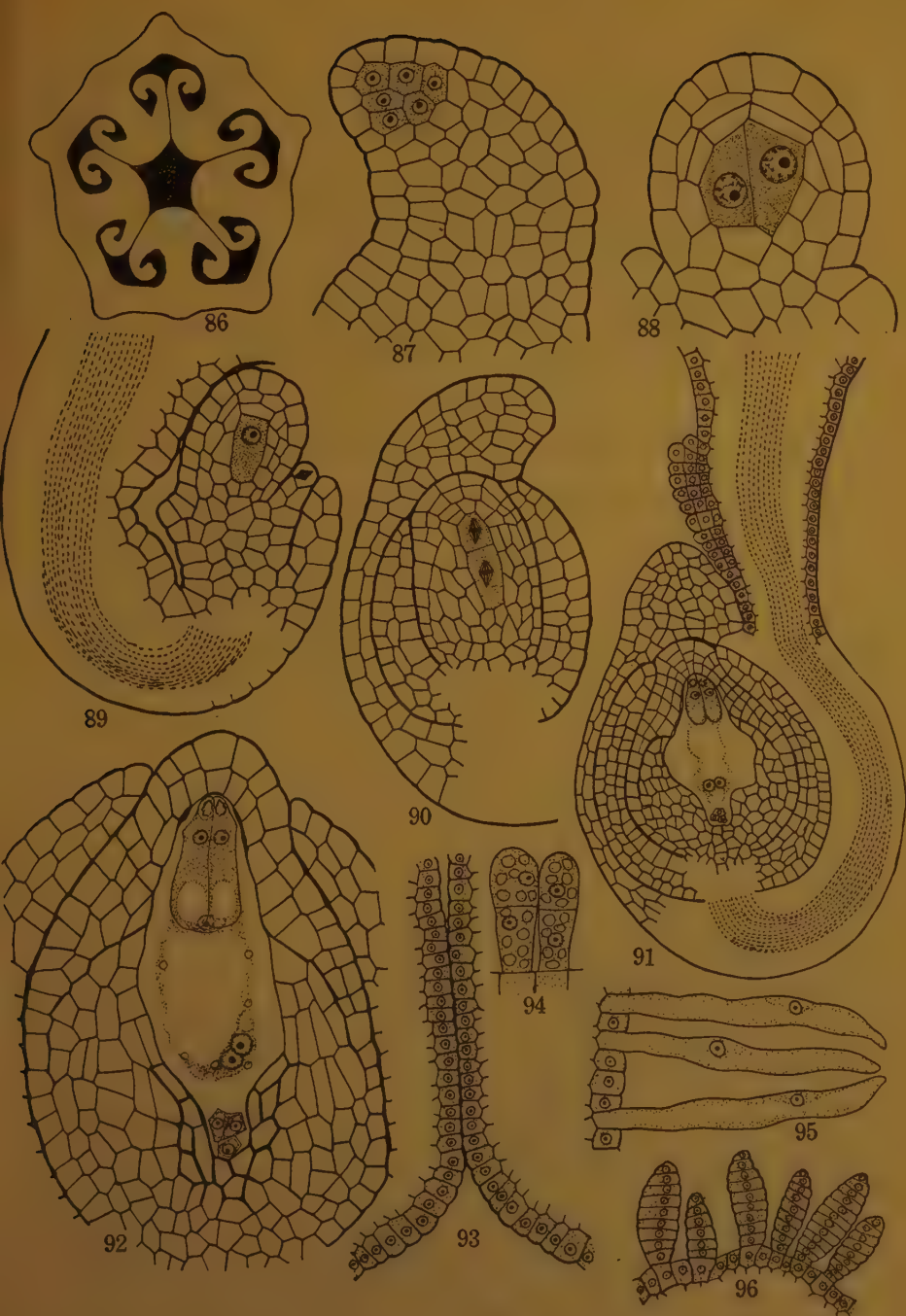
Fig. 73. L.s. loculus of ovary,  $\times 80$ . Fig. 74. T.s. loculus of ovary,  $\times 155$ . Fig. 75. Ovule primordium with multicellular archesporium,  $\times 500$ . Fig. 76. Ovule showing first division of primary parietal cell,  $\times 715$ . Fig. 77. Ovule with integument initials and parietal layers,  $\times 645$ . Fig. 78. Ovule with a linear tetrad,  $\times 500$ . Fig. 79. Mature embryo-sac,  $\times 1065$ . Fig. 80. Mature ovule: note the glandular cells at the base of the funicle,  $\times 500$ . Fig. 81. Ovule penetrated by a pollen tube,  $\times 500$ . Fig. 82. Young seed showing hypostase,  $\times 40$ . Fig. 83. Part of the above magnified,  $\times 500$ . Figs. 84 and 85. Hairs from ovary wall and sepals respectively,  $\times 355$ .

has been studied in *Helicteres isora* (Figs. 82, 83). The development of the embryo keys out to *Urtica* variation of the Asterad Type.

After a period of rest, the fertilised egg undergoes a transverse division and gives rise to the basal cell *cb* and a terminal cell *ca* (Figs. 134, 160, 175). Usually the terminal cell divides vertically and the basal cell transversely at about the same time forming a T-shaped proembryo of which the lower two cells are designated *m* and *ci* (Figs. 135, 163, 176). Occasionally the division in one cell precedes that in the other so that a 3-celled proembryo results. In case the basal cell divides earlier, the embryo is linear (Fig. 162). If the terminal cell divides earlier, a T-shaped embryo results (Fig. 161). In the latter case, the segmentation gives definite evidence for the derivation of *m* from *cb*. The two juxtaposed cells of the terminal tier undergo a vertical division forming circumaxially arranged quadrants designated *q*. *M* divides vertically and *ci* transversely forming *n* and *n'*. The next divisions in cells of *q* are obliquely vertical and result in two layers of cells *a* and *b*. *n* divides vertically and *n'* transversely forming *o* and *p*. Now the embryo is 5-tiered and the destination of the tiers is as follows: *q* forms the stem tip and cotyledons; *m* develops into the hypocotyl; *n* gives rise to the root tip and *o* functions as the hypophysis and fills out the dermatogen of the root tip and root cap; *p* forms the suspensor which is usually short.

In *Klienhowia hospita*, sometimes the divisions in *cb* or its derivatives are irregular. The basal cell may undergo a vertical instead of a transverse division (Fig. 164), or *ci* may undergo first a vertical division (Fig. 166). But as the later divisions are transverse, the number of tiers and their destination remain unchanged. Such irregularities in behaviour of the derivatives of the basal cell were also noticed in *Tilia platyphyllos* by Souèges (1941), but Johansen (1950) feels that they are not of such significance as to necessitate the erection of a separate variation.

The dermatogen initials are demarcated first in *m* and then in *q* and *n*. One of the inner group of cells (*b*) may sometimes divide in an oblique manner giving rise to what looks like an epiphyseal cell, but by further divisions the derivatives of this cell get mixed up with those of the remaining cells. The number of root cap initiating layers varies from one to two. The suspensor remains 1-celled for a pretty long time in *Pentapetes* and *Klienhowia* but in *Abroma augusta* it divides early and becomes several celled. In the mature seed, the cotyledons are large and foliaceous. They may be straight as in *Abroma augusta* (Figs. 154–156) or variously folded as in *Klienhowia hospita* (Fig. 172).



FIGS. 86-96. *Abroma augusta*



Fig. 86. T.s. ovary,  $\times 30$ . Fig. 87. Ovule primordium with multicellular archesporium,  $\times 500$ . Fig. 88. Ovule with two functional megaspore mother cells,  $\times 715$ . Fig. 89. Ovule showing development of integuments and parietal layers,  $\times 425$ . Fig. 90. Formation of linear tetrad,  $\times 285$ . Fig. 91. Mature ovule; note glandular cells on the funicle,  $\times 200$ . Fig. 92. Nucellus of mature ovule; note the circular patches on the synergids,  $\times 425$ . Fig. 93. Glandular epidermal cells of carpellary wall which function as transmitting tissue,  $\times 285$ . Fig. 94. Glandular cells of the funicle rich in cytoplasm and starch grains,  $\times 285$ . Fig. 95. Cells of carpellary wall grown into hairs after fertilisation,  $\times 285$ . Fig. 96. Glandular hairs from the sepals,  $\times 285$ .

and *Pentapetes phanicea* (Figs. 185–187). The cells of the embryo are laden with starch and other food materials. In *Klienhowia hospita* some of the cells of the radicle become papillate (Fig. 171).

### SEED COATS

The post-fertilisation growth in the integuments is shown in the following table:

Name of plant	Layers in outer integument	Layers in inner integument	Layers in testa	Layers in tegmen
<i>Sterculia colorata</i>	3	4	10–12	25–30
<i>Pterospermum heyneanum</i>	3	4	6–12	8–10
<i>Pentapetes phanicea</i>	3	4	3–5	6–8
<i>Buettneria herbacea</i>	2	3	3–4	8–10
<i>Abroma augusta</i>	2	5	2	8–10
<i>Wilhelmsia tosa</i>	2	2	2	8–10
<i>Klienhowia hospita</i>	3	4	6–10	10–12

After fertilisation, the integuments increase in thickness, the tegmen becoming more massive than the testa. Starch grains appear in the cells of the seed coats in *Abroma*. The integuments are thicker in the chalazal region than in the region of the micropyle. They show the maximum thickness at about the time when the embryo has the shape of a large globular mass. The thickness of the coats given above was observed about the middle of the seed.

The testa in general is smooth. Its outer epidermis consists of tangentially flattened cells filled with tannin. In *Abroma augusta*, in which the testa does not increase in thickness after fertilisation, the 2 layers of the testa are loosely attached and the outer epidermis does not accumulate tannin (Fig. 208). Sometimes tannin is seen in isolated groups of cells which give a speckled appearance to the surface view of the testa (Fig. 197). In *Klienhowia hospita* some of the epidermal cells grow out into short spinescent processes (Fig. 207). The inner epidermis of the outer integument consists of tangentially flattened cells except in *Buettneria herbacea* in which they are somewhat



FIGS. 97-106. *Buettneria herbacea*

Fig. 97. L.s. loculus of ovary showing the two superposed ovules,  $\times 200$ . Fig. 98. Ovule showing full grown megaspore mother-cell,  $\times 425$ . Fig. 99. Ovule with 1-nucleate embryo-sac,  $\times 425$ . Fig. 100. Upper ovule of the loculus with 8-nucleate embryo-sac, in contact with the placental obturator,  $\times 355$ . Fig. 101. Lower part of the embryo-sac invested by thick-walled cells,  $\times 715$ . Fig. 102. Ovule of the lower tier showing entry of pollen tube,  $\times 355$ . Fig. 103. Micropylar part of the embryo-sac showing one egg-like synergid,  $\times 855$ . Fig. 104. A loculus of ovary showing degeneration of ovules,  $\times 170$ . Fig. 105. Loculus of a fruit with one developing seed; note the spinescent outgrowths on the fruit wall,  $\times 30$ . Fig. 106. Glandular hairs on the ovary wall,  $\times 285$ .

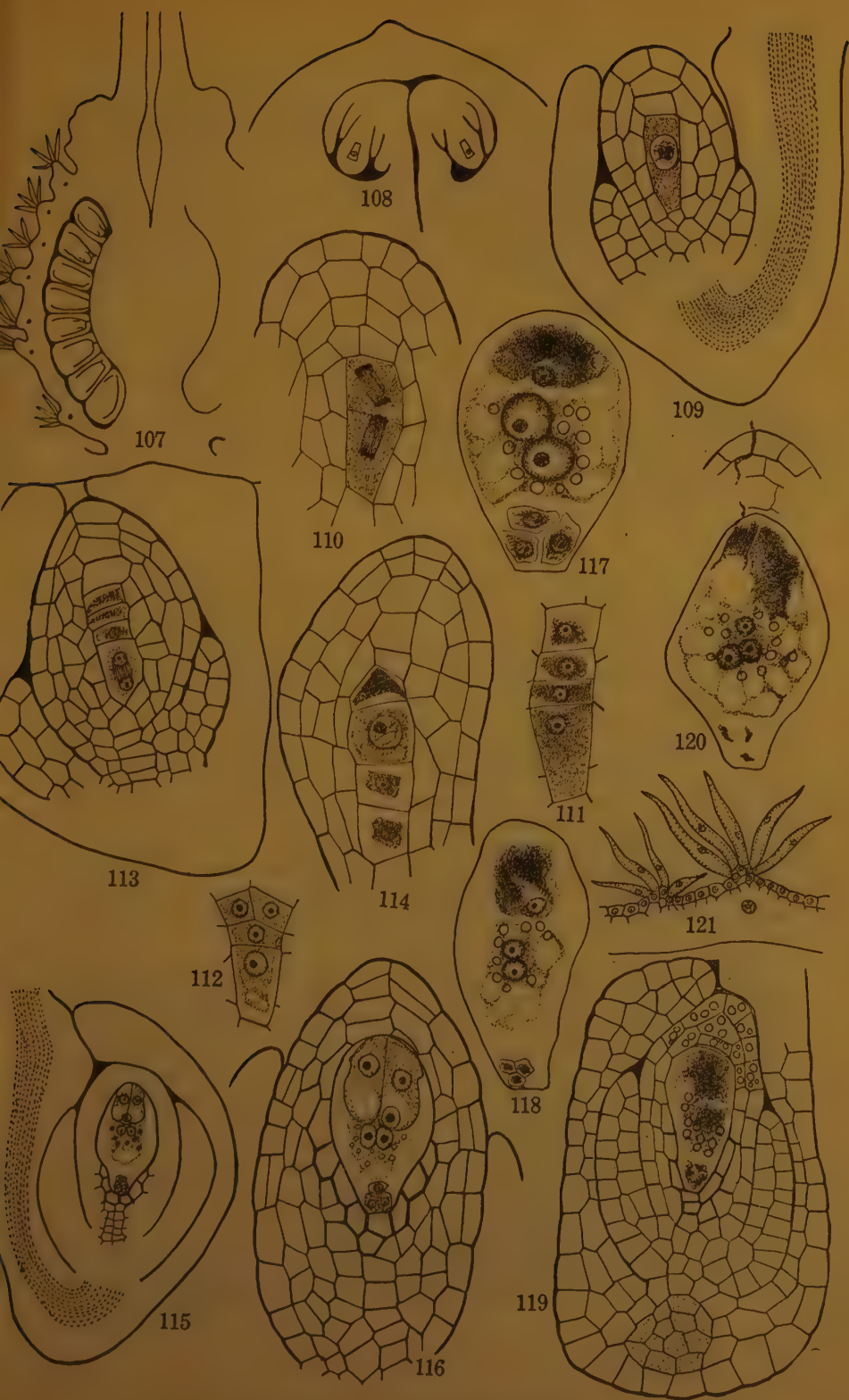
radially elongated (Fig. 199). Sometimes these cells also contain tannin.

In *Sterculia*, *Pterospermum* and *Klienhowia*, vascular bundles are given off into the testa from the chalazal end of the ovular trace. In *Klienhowia hospita*, these strands form a plexus in the lower third of the seed. In *Sterculia colorata* (Figs. 190–192) 6–9 prominent strands arise and extend nearly to the micropyle giving off a few branches on the way. In *Pterospermum heyneanum*, the strands are more numerous and their branches form an anastomosing system throughout the testa (Figs. 194–196). Similar integumentary vascular bundles have been reported in *Thespesia*, *Gossypium* and *Ingenhousia* (Reeves, 1936) of Malvaceæ and *Pachira aquatica* of Bombacaceæ (C. V. Rao, 1954).

The cells of the outer epidermis of the outer integument become radially elongated and form the palisade layer as in other Malvales. The inner tangential and radial walls become thickened so that the lumens of the cells are seen only in the outer halves. The palisade layer shows a prominent light line (Fig. 209). The inner half of the cell wall stains deeply with phloroglucinol showing thereby that it is lignified while the outer non-stainable zone is made of cellulose. Except in *Helicteres isora*, 1–3 layers of cells immediately below the palisade layer accumulate tannin and constitute the 'inner pigment layer'. In *Sterculia colorata* in which the tegmen is much thicker than in others, this layer is of greater thickness (Fig. 192). In *Helicteres isora*, the pigment layer develops in the median region of the tegmen and is separated from the epidermal layers by 1–3 layers of colourless cells (Figs. 201, 202). The inner epidermis of the tegmen consists of tangentially flattened tannin-filled cells, called 'the fringe tissue', and the median layers are composed of thin-walled parenchyma which are resorbed in the seed. In *Sterculia colorata*, where the nucellus is crushed and absorbed much earlier than in others, these parenchymatous cells seem to constitute an important nutritive tissue for the growing embryo. The cells of the fringe tissue stain deeply and their cell walls are lignified. The structure of this layer in *Sterculia colorata* differs from that of others in that they do not show tannin nor do their cell walls stain deeply. They show reticulate thickenings, the presence of which is considered by Netolitzsky (1926) to be a primitive feature.

The seed coat structure of *Pentapetes phanicea* deserves special mention. The cells of the inner integument in the region of the micropyle become much elongated; their cell walls become lignified and they develop reticulate thickenings characteristic of tracheids (Figs. 188,





FIGS. 107-121. *Guazuma tomentosa*



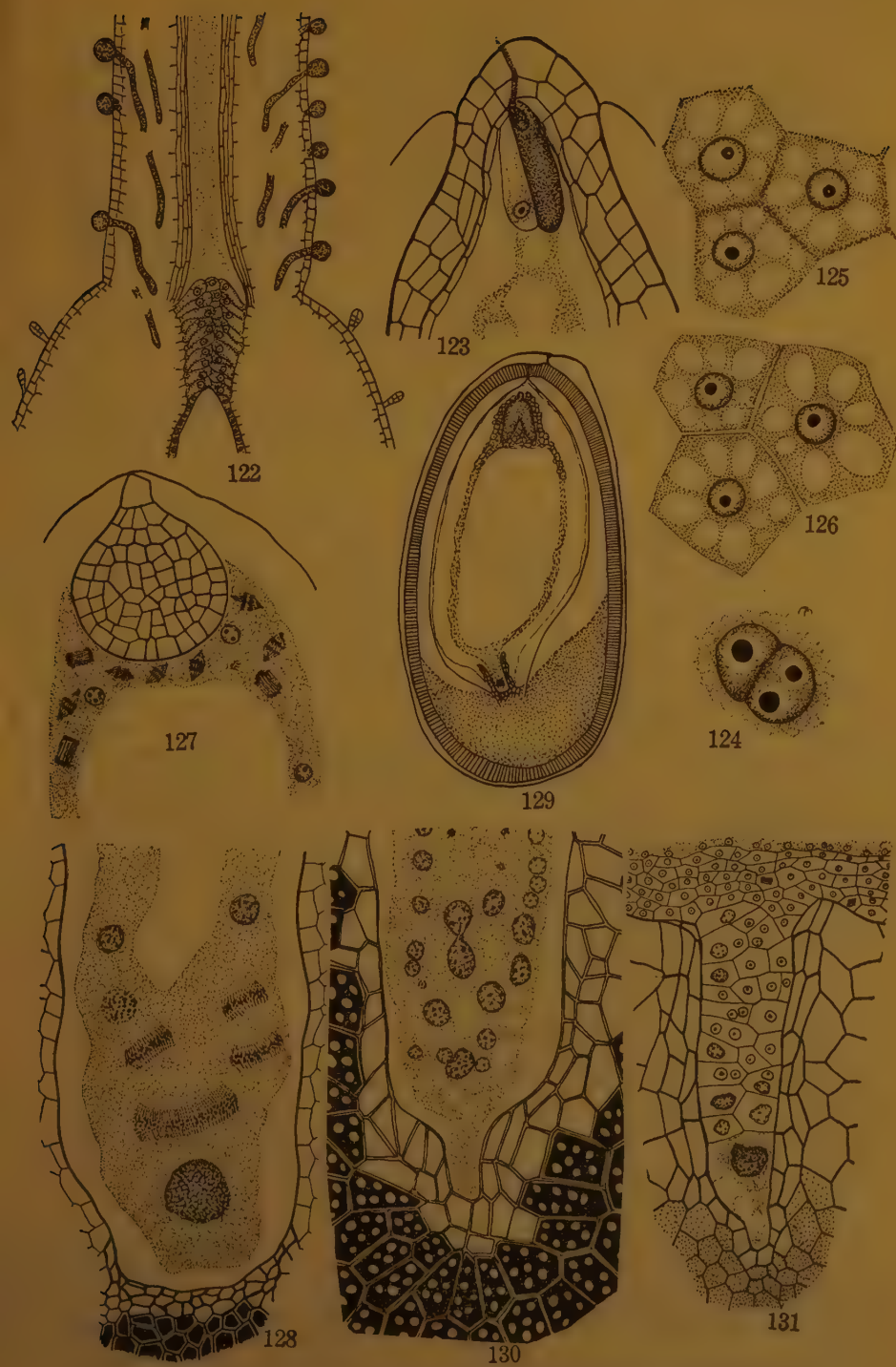
Fig. 107. L.s. ovary,  $\times 50$ . Fig. 108. T.s. loculus of ovary,  $\times 135$ . Fig. 109. Ovule with full grown megaspore mother cell,  $\times 425$ . Fig. 110. Nucellus showing formation of linear tetrad,  $\times 715$ . Fig. 111. A linear tetrad,  $\times 715$ . Fig. 112. A T-shaped tetrad of megaspores,  $\times 425$ . Fig. 113. Ovule showing first free nuclear division in the functional megaspore,  $\times 425$ . Fig. 114. Nucellus with linear tetrad in which the second megaspore from the micropylar end is enlarging,  $\times 715$ . Fig. 115. Mature ovule,  $\times 355$ . Fig. 116. Nucellus of fertilisable ovule showing embryo-sac and socket of thick-walled cells,  $\times 715$ . Figs. 117 and 118. Degenerating embryo-sacs,  $\times 500$ . Fig. 119. Ovule with degenerating embryo-sac; note the starch grains in parietal cells,  $\times 425$ . Fig. 120. A degenerating embryo-sac being penetrated by a pollen tube,  $\times 715$ . Fig. 121. Glandular hairs from the ovary wall,  $\times 135$ .

189). These cells might serve in the quick transport of water during the germination of seed. Similar cells were reported by Venkateswarlu (1937) in *Sonneratia*. Guilford and Fisk (1952) described that in *Mimulus*, the cells of the placenta and funicle by the side of the embryo become tracheidal. In the mature seed, the testa remains membranous. The tegmen consists of the palisade layer, the fringe tissue and the crushed remnants of the pigment layer.

#### STERILITY

Sterility is common in species of *Dombeya*, *Sterculia* and *Guazuma*. This is ascribable to both infertile pollen grains as well as to degeneration of embryo-sacs. In *Guazuma tomentosa*, sometimes all the flowers of an inflorescence drop off without forming a single fruit. In *Dombeya spectabilis*, the flowers wither with all their parts in tact. The ovaries form conical woody 'fruits', 1-1½ cm. long, but only with abortive seeds. In *Sterculia* species also, very few fruits are developed. In all these species, the embryo-sacs in many ovules degenerate after reaching the 8-nucleate stage (Figs. 36, 61, 104, 117-120). In *Dombeya mastersii*, occasionally all the megaspores of a tetrad degenerate. Still the ovules continue to develop for some time and occur alongside with the normal ones in ovaries ready for pollination. In the process of degeneration of an embryo-sac, the synergids seem to be affected first, then the egg and lastly the polar nuclei. After all the cells have degenerated, the cytoplasm forms a deep staining mass and finally the ovule collapses.

In *Guazuma tomentosa*, sometimes degeneration of the embryo-sac commences before the flowers open. In a few cases, the pollen tubes were seen penetrating ovules in which the egg apparatus was already showing signs of degeneration (Fig. 120). In one case, a male nucleus was found in contact with the polar nuclei which alone were persisting in the embryo-sac. In such cases, the penetration of the pollen tube might stimulate the ovary to form the 'fruit' and the the ovule to develop into the 'seed' but since the egg had already degenerated, there would be no embryo and the seeds would be exembryonate. The presence of the male nucleus in contact with the polar nuclei makes probable the formation of some endosperm. An examination of a number of seeds from mature fruits of *Sterculia colorata* and *Pterospermum heyneanum* revealed that associated with seeds containing large embryos there were some as large as the normal seeds, with seed



FIGS. 122-131. Fertilisation, endosperm and seed development in Sterculiaceae

Fig. 122. L.s. top of the ovary and part of the style of *Abroma augusta* showing stylar canal and germinating pollen grains. Note that the stylar canal is occluded by glandular cells at its base,  $\times 45$ . Fig. 123. Micropylar part of nucellus and embryo-sac of *Abroma augusta*, showing entry of pollen tube,  $\times 425$ . Fig. 124. Fusion of a male gamete with a polar nucleus in *Pentapetes phænicea*,  $\times 855$ . Figs. 125 and 126. Cell formation in endosperm of *Klienhowia hospita* by indentation,  $\times 425$ . Fig. 127. Upper part of embryo-sac of *Pentapetes phænicea* showing globular embryo, endosperm aggregation and free nuclear divisions,  $\times 285$ . Fig. 128. Lower part of embryo-sac of young seed of *Pentapetes phænicea* showing polyploid endosperm nuclei and their divisions,  $\times 285$ . Fig. 129. L.s. developing seed of *Abroma augusta*, note the postament,  $\times 15$ . Fig. 130. Lower part of embryo-sac of *Abroma augusta* surrounded by thick-walled tannin and starch-bearing cells; note the nuclear fusions in endosperm,  $\times 355$ . Fig. 131. Same as above but from older seed; endosperm has become cellular; note the degenerating gigantic nucleus at lower end,  $\times 135$ .

coats normally formed, which had only a large cavity inside and showed no trace of an embryo. In some cases, however, they showed a little endosperm.

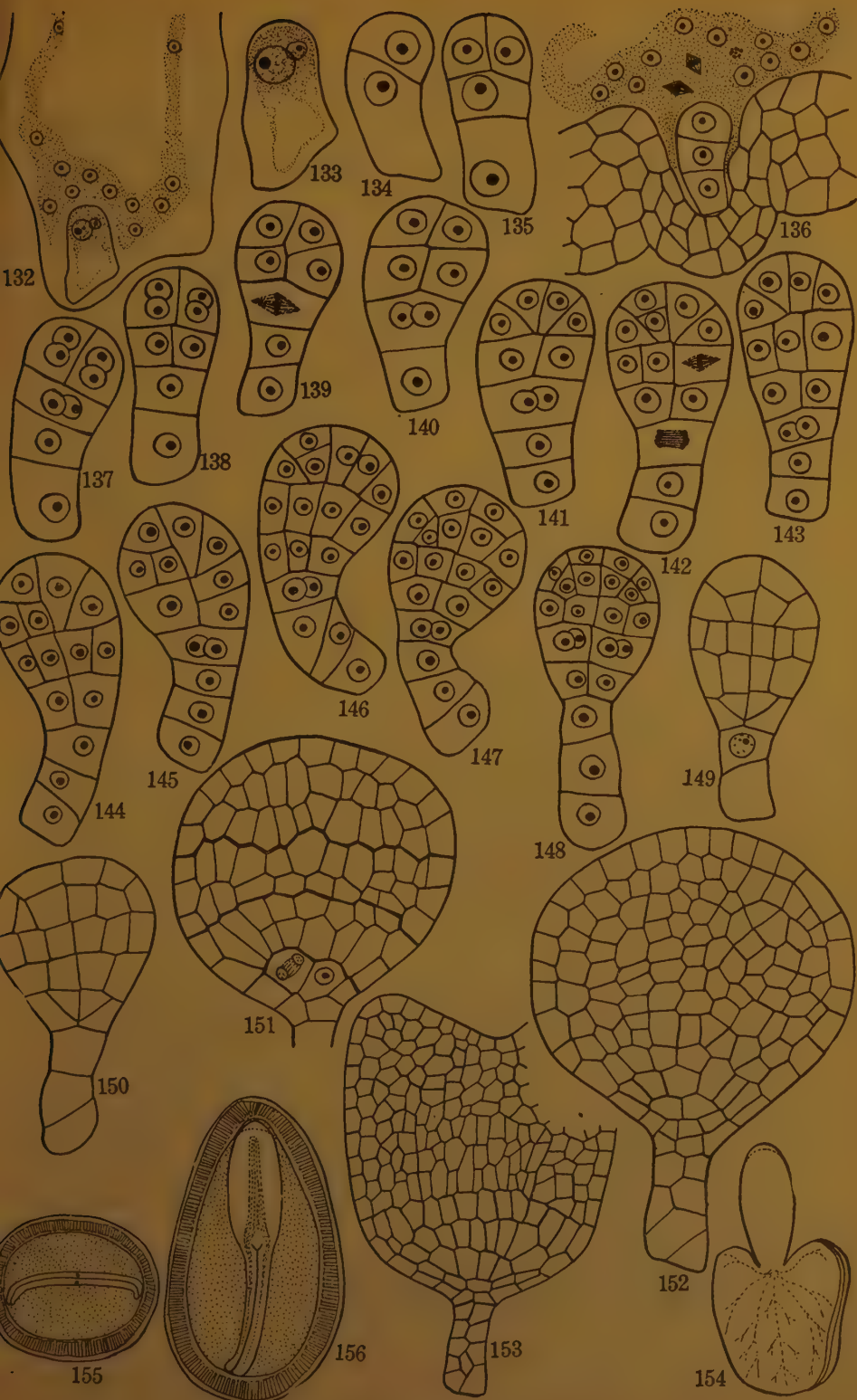
#### DISCUSSION

On the basis of several morphological and anatomical features like the predominance of pentacyclic flowers, presence of 3-bundled staminal traces, hood-like outgrowths for stamens, gynophore, cortical vascular system in the receptacle (*Pterospermum*) and apocarp (Sterculia), the writer (C. V. Rao, 1952) regards Sterculiaceæ to be the most primitive family among the Malvales. This conclusion is supported by embryological findings. Smooth-walled pollen grains which are regarded by Wodehouse (1936) as more primitive than spinescent ones are found in 4 out of the 5 tribes of the family studied so far. Other features which indicate its primitiveness are: secondary increase in the sporogenous tissue of the anther, secondary increase in the sporogenous tissue of the ovule (*Pterospermum suberifolium*), multicellular archesporium with several functional cells, etc. The following seed characters exhibited by the family are also to be considered primitive according to the criteria of Netolitzsky (1926): crassinucellate ovules, 2-3 layered integuments which cover the straight nucellus and are separated from each other and from the nucellus by a cuticle, the unbranched vascular bundle of the raphe, early resorption of the nucellus, smooth testa, copious endosperm and embryo laden with food.

Among Sterculiaceæ, Sterculiæ stands apart from the rest of the tribes by its apetalous and unisexual flowers and apocarpous pistil. The nucellus of the developing seed in *Sterculia colorata* is consumed much earlier than in other genera and reticulate thickenings are seen on the inner epidermis of the inner integument. Netolitzsky (1926) remarks "delicate markings on the cell walls of the inner epidermis of the inner integument designate the seed as primitive within larger or smaller groups".

Among the remaining tribes, the genus *Pterospermum* seems to be the most primitive anatomically, morphologically and embryologically. The flowers are pentacyclic and floral parts other than the carpels do not show connation. The presence of hood-like outgrowths of the





FIGS. 132-156. *Abroma augusta*



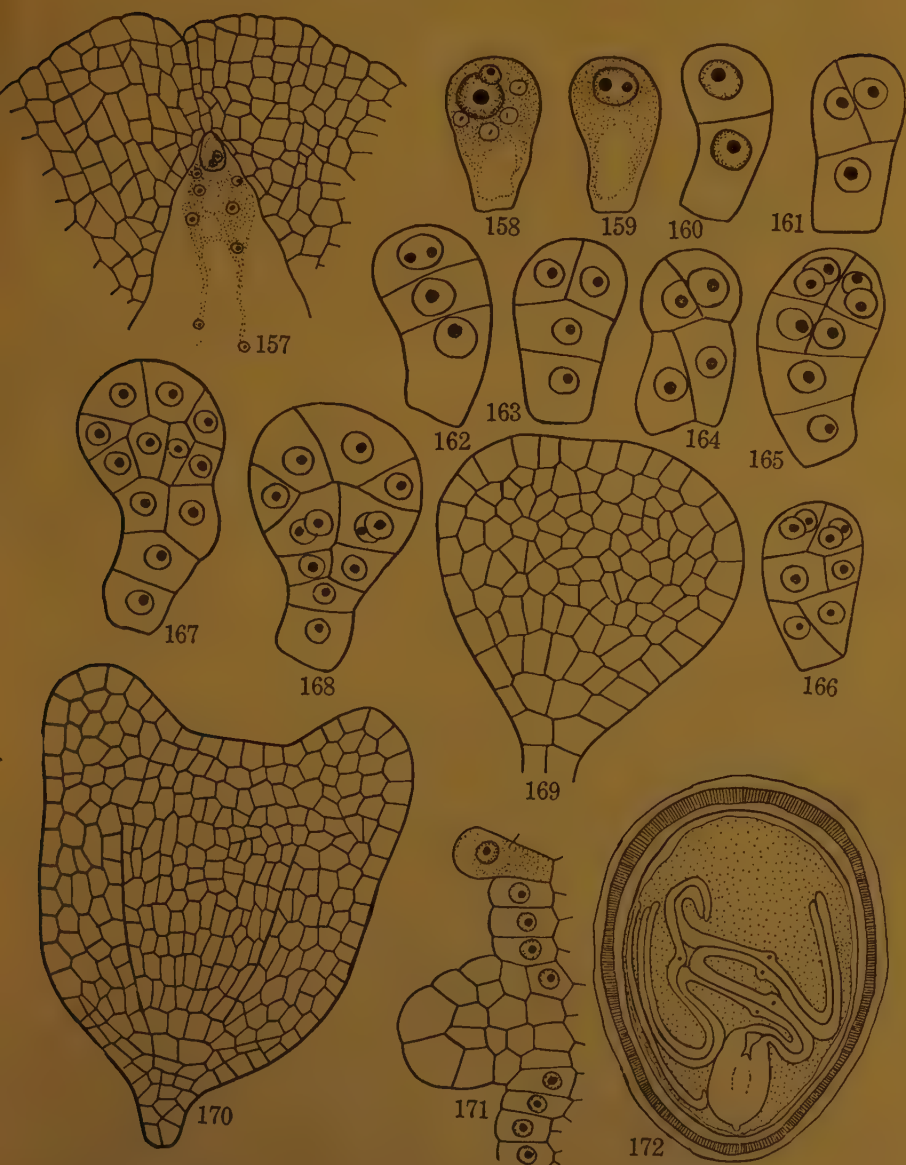
Fig. 132. Micropylar part of the embryo-sac with a few endosperm nuclei and egg in the process of fertilisation,  $\times 355$ . Figs. 133-153. Various stages in the development of the embryo. Figs. 136 and 153,  $\times 355$ ; the rest,  $\times 425$ . Fig. 154. Mature embryo,  $\times 8$ . Figs. 155 and 156. T.s. and L.s. of mature seed,  $\times 9$ .

connectives of stamens and the cortical vascular system of the gynophore are regarded as very primitive features (Parkin, 1951; Ozenda, 1952). Embryologically, the presence of multicellular archesporium in the ovule with a secondary increase of sporogenous tissue, several functional cells and development of double and triple embryo-sacs in an ovule, secondary increase in sporogenous tissue of the anther, etc., are primitive features. In other genera of *Dombeyaceae* (*Dombeya*, *Pentapetes*) and *Guazuma*, etc., the archesporium of the ovule is 1-celled. In *Buettneria*, the lateral stamens of the triplets of the outer whorl (present in the above genera) are suppressed. Embryologically also the presence of a placental obturator in this genus can be considered as a specialised feature. *Helicteraceae* (*Helicteres* and *Klienhowia*) shows some advanced morphological and embryological features. The flowers are zygomorphic and in *Helicteres* they are not only tetracyclic but also the median stamens of the triplets of the outer whorl are suppressed. The pollen grains are triangular and flattened. The integuments cover the nucellus incompletely and glandular cells are present on the placenta which help in nourishing the pollen tubes. A hypostase is found in the nucellus of the developing seed. Netolitzsky (1926) considers smooth testa as more primitive than one with outgrowths. While the testa in all other genera is smooth, that of *Klienhowia* shows spinescent outgrowths from some of its epidermal cells. The *Hermannieae* (*Melochia* and *Waltheria*) seems to be the most highly evolved tribe of the family. The flowers are typically tetracyclic and pentamerous in *Melochia*, while in *Waltheria* there is the reduction of carpels to one. The embryological features which support such a conclusion are: the direct functioning of the sporogenous cells of the anther (*Melochia*) and presence of plasmodial tapetum, both features being found in *Malvaceae*, which is considered to be the most highly evolved family of *Malvales*.

#### SUMMARY

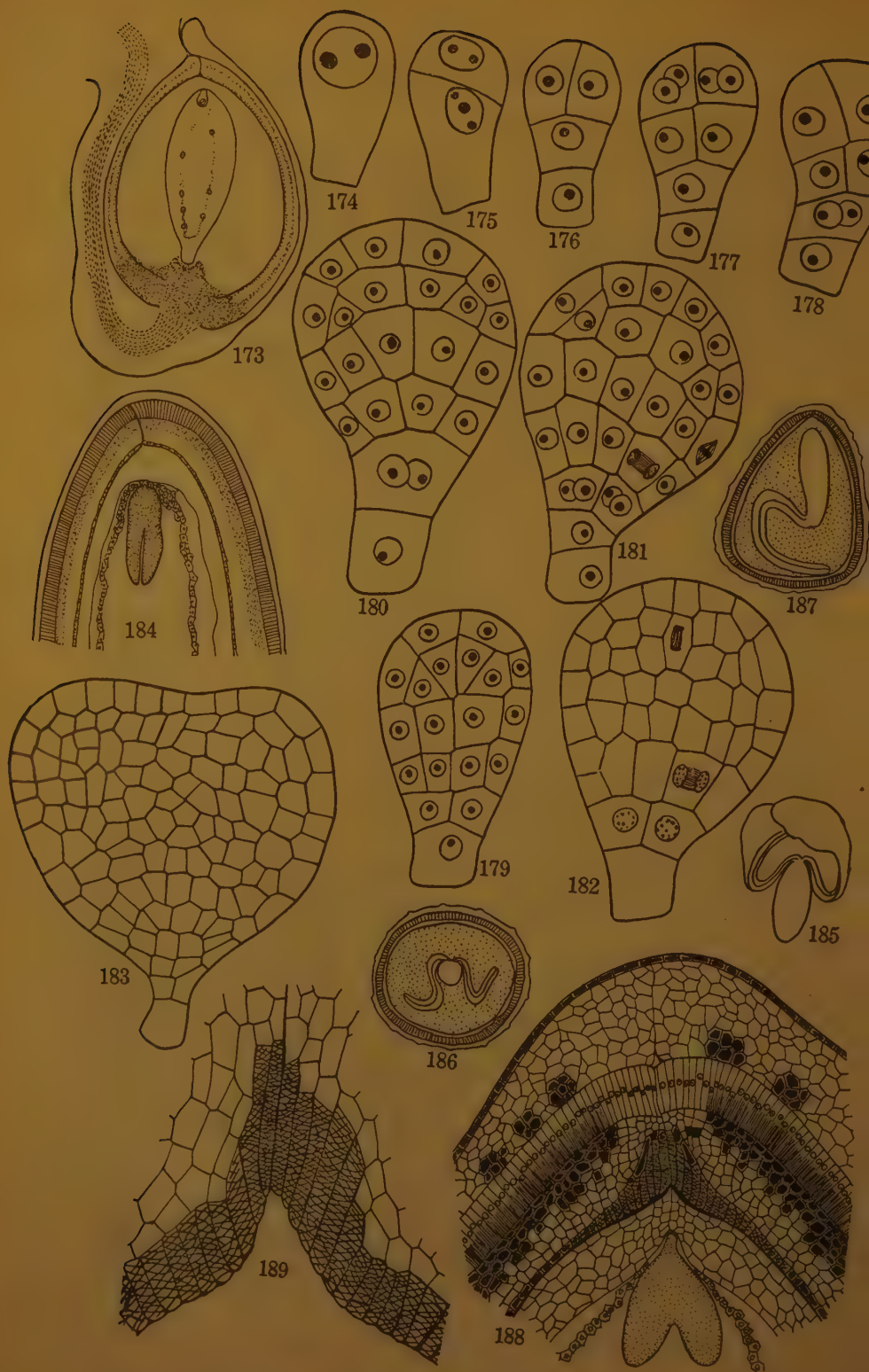
Development of the anther, pollen, ovule and embryo-sac has been studied in the following 10 species: *Sterculia colorata* Roxb., *S. fatida* L., *Pentapetes phanicea* L., *Dombeya spectabilis* Bojer., *D. mastersii* Hook., *Abroma augusta* L., *Guazuma tomentosa* Kunth., *Buettneria herbacea* Roxb., *Klienhowia hospita* L., and *Helicteres isora* L. Development of embryo was followed in *Pentapetes phanicea*, *Abroma augusta* and *Klienhowia hospita* and seed development in *Buettneria herbacea* and *Helicteres isora*. Seed structure of *Sterculia colorata* and *Pterospermum heyneanum* is described and finally, the embryological features of the family are discussed.

The anther wall is 4-5 layered. The cells of the epidermis and connective accumulate tannin and sometimes starch grains. Dehiscence of the anther is brought about by fibrous endothecium and a



FIGS. 157-172. Embryo and seed development in *Klienhovia hospita*

Fig. 157. Upper part of nucellus with fertilised egg and micropylar aggregation of endosperm,  $\times 200$ . Figs. 158-170. Various stages in the embryo development,  $\times 425$ . Fig. 171. Suspensor and epidermal cells of root tip; note the papillate cells,  $\times 355$ . Fig. 172. L.s. seed,  $\times 30$ .



Figs. 173-189. Development of embryo and seed in *Pentapetes phænicea*



Fig. 173. L.s. young seed with fertilised egg and a few endosperm nuclei,  $\times 50$ . Figs. 174–183. Various stages in development of embryo,  $\times 425$ . Fig. 184. L.s. upper part of seed,  $\times 30$ . Fig. 185. Entire embryo,  $\times 8$ . Figs. 186 and 187. T.s. and L.s. mature seed,  $\times 8$ . Fig. 188. L.s. upper part of the seed; note the tracheidal cells in the micropylar region,  $\times 200$ . Fig. 189. Part of the above magnified,  $\times 255$ .

well-defined stomium. The innermost layer of wall cells forms the tapetum of the secretory type. The sporogenous cells of the anther show a secondary increase. Microspore tetrads are mostly tetrahedral and cytokinesis takes place by furrowing. The pollen grains are shed in the 2-nucleate condition and their cytoplasm is packed with starch grains. The pollen grains are triangular and oblately flattened in *Helicteres*, ellipsoidal in *Sterculia* and spherical in the rest. In the *Dombeyæ* they are spinescent. They are triporate in all species and in *Buettneria* the germ pores are raised on papillate projections of the exine.

The ovules are crassinucellate, bitegmic and anatropous. A zig-zag micropyle is formed by both the integuments in *Dombeya*, *Pentapetes*, *Sterculia* and *Klienovia*. In *Guazuma*, *Buettneria* and *Abroma* it is formed only by the outer integument, the inner covering less than half of the nucellus. In *Helicteres*, both the integuments stand low and the nucellus of the fertilisable ovule protrudes nakedly. A nucellar cap is formed in all species. Cells in the chalaza accumulate tannin and starch and develop thick walls. In *Abroma* a postament develops in the seed and in *Helicteres* a hypostase is organised in the nucellus of the young seed.

The archesporium of the ovule is multicellular, but only one cell functions. Megaspore tetrads are mostly linear and embryo-sac develops according to *Normal*-type. The synergids are hooked and in *Pentapetes* and *Abroma* they show circular deep staining patches near the micropylar ends which may be analogous to filiform apparatus. Polar nuclei remain separate till the time of fertilisation. The three antipodals are ephemeral. A case of an embryo-sac with reversed polarity was noticed in *Helicteres isora*.

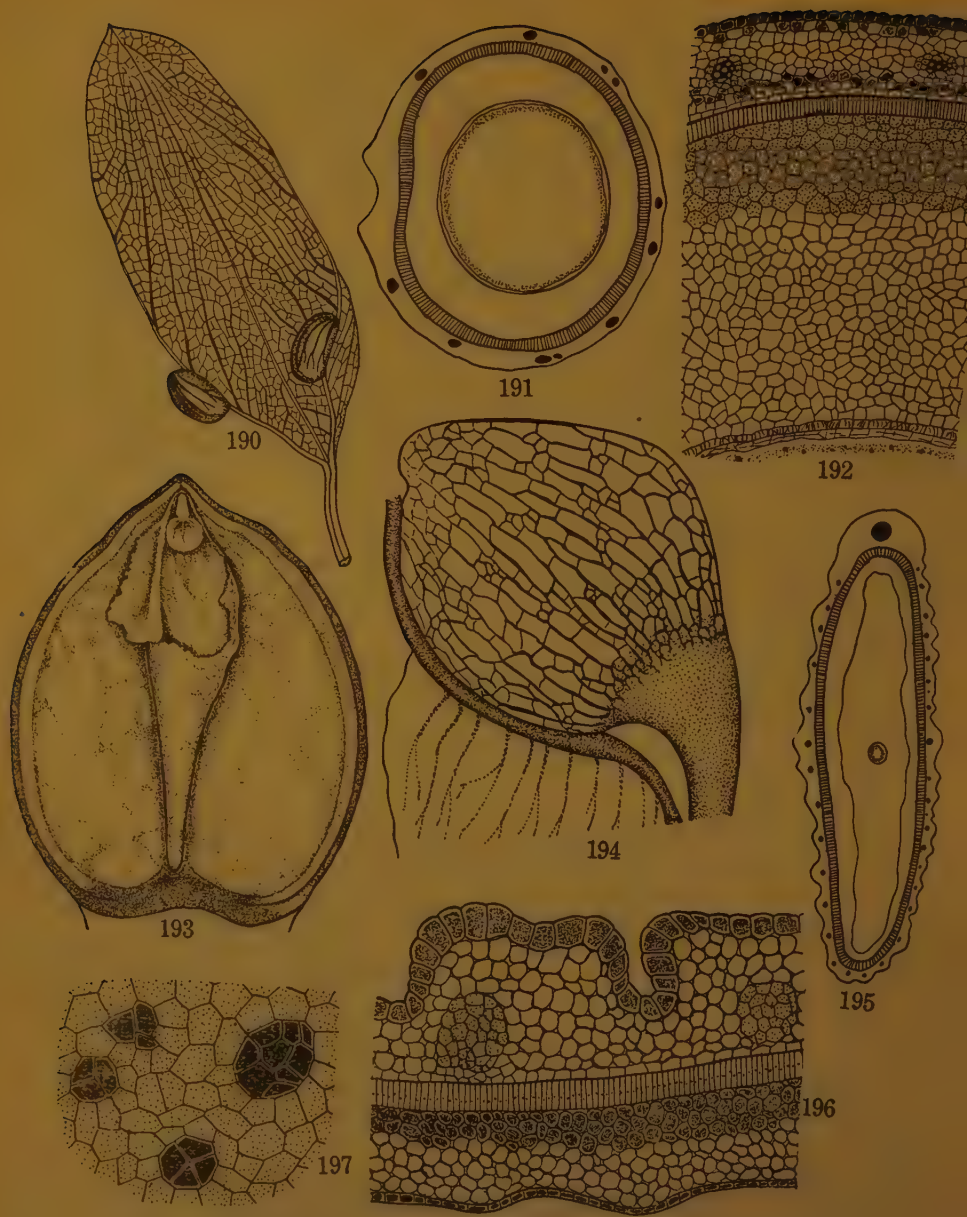
In *Buettneria herbacea* there is a hairy placental obturator for the upper tier of ovules. The cells of the funicle in *Sterculia colorata* and *Abroma augusta* are radially elongated and richly protoplasmic and seem to serve in nourishing the pollen tubes. Similar cells are seen at the base of the funicle in *Helicteres*.

Fertilisation is porogamous. The endosperm is nuclear and becomes cellular at a late stage in seed development by the process of indentation. Large polyploid nuclei are found in the antipodal part of the endosperm in *Pentapetes* and *Abroma*. The mature seeds are endospermic but devoid of perisperm.

Development of the embryo conforms to the *Urtica* variation of the Asterad Type. The suspensor is small.

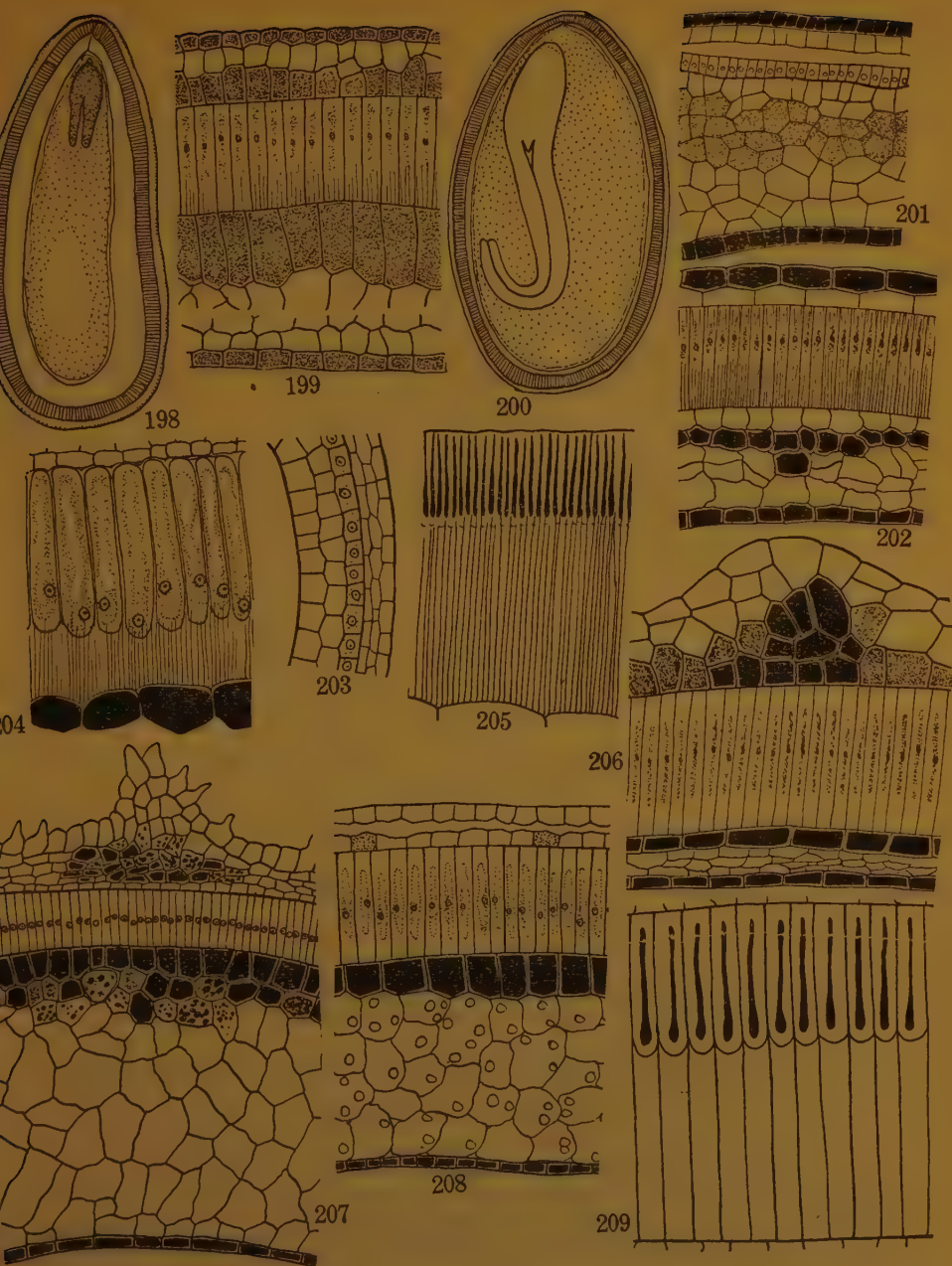
The outer integument develops into a membraneous testa. In *Pterospermum* and *Sterculia* it is thicker than in others and shows





FIGS. 190-197. Seed and seed coat structure in Sterculiaceae

Fig. 190. A dehiscent fruitlet of *Sterculia colorata*,  $\times 1$ . Fig. 191. T.s. seed of *Sterculia colorata*,  $\times 5$ . Fig. 192. Seed coats of *Sterculia colorata*; note the delicate markings on the inner epidermis of the inner integument,  $\times 75$ . Fig. 193. L.s. seed of *Pterospermum heyneanum*,  $\times 3$ . Fig. 194. Surface view of the seed of *Pterospermum heyneanum*; note the integumentary vascular bundles,  $\times 3$ . Fig. 195. T.s. seed of *P. heyneanum*,  $\times 6$ . Fig. 196. Seed coats of the same in sectional view,  $\times 75$ . Fig. 197. Surface view of the testa of *Pentapetes phœnicea* showing groups of tannin-bearing cells,  $\times 135$ .



Figs. 198-209. Seed and seed coat structure in Sterculiaceae

Fig. 198. L.s. seed of *Buettneria herbacea*,  $\times 10$ . Fig. 199. Seed coats of *Buettneria herbacea*,  $\times 135$ . Fig. 200. L.s. seed of *Helicteres isora*,  $\times 30$ . Figs. 201 and 202. Seed coats of *Helicteres isora* from young and somewhat old seeds. Fig. 201,  $\times 535$ ; Fig. 202,  $\times 135$ . Figs. 203-206. Integuments and seed coats of *Pentapetes phoenicea*,  $\times 355$ . Fig. 207. Seed coats of *Klienhowia hospita*,  $\times 75$ . Figs. 208 and 209. Seed coats from young and old seeds of *Abroma augusta*. Fig. 208,  $\times 135$ ; Fig. 209,  $\times 235$ .

integumentary vascular bundles. In *Klienovia* some of the cells of the testa become papillate. The outer epidermis of the inner integument develops into the palisade layer and 1 or 2 layers of cells below it into the pigment layer. The next few layers of parenchymatous cells become crushed in seed and the innermost layer persists in the form of fringe tissue.

The embryological features of the family, like those of floral anatomy, show that the family is the most primitive among Malvales. On these data the tribes of the family can be arranged in the following evolutionary sequence: Sterculiæ, Dombeyæ, Buettneriæ, Helicteræ and Hermannæ.

#### ACKNOWLEDGEMENTS

The writer wishes to express his grateful thanks to Prof. J. Venkateswarlu and Prof. A. C. Joshi for their kind interest in the work and helpful suggestions. His thanks are also due to Dr. K. Subrahmanyam, Mr. C. S. Prakasa Rao and Mr. R. Seshagiri Rao for the materials they kindly sent.

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# A SYSTEMATIC ACCOUNT OF THE DIATOMS OF BOMBAY AND SALSETTE

## PART II

### Pennales : Sub-orders—Biraphidineæ (Contd.)

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THIS paper is in continuation of the one which was published in this journal (Vol. XXXI, No. 3, 1952, pp. 117-151), and is the second of the series. The translation into Latin of the new diagnoses has been done by Rev. Fr. H. Santapau, Bombay. The authors record their grateful thanks to him.

#### IV. Suborder

#### BIRAPHIDINEÆ (Contd.)

##### (2) Family

##### NAVICULACEÆ (Contd.)

##### (a) Subfamily

##### Naviculoideæ (Contd.)

#### Genus *Gyrosigma* Hassal, 1845

#### 62. *Gyrosigma acuminatum* (Kütz.) Rabh.

(Fig. 62)

Smith, W., *Syn. Brit. Diat.*, Vol. I, 1853, p. 66, pl. 22, fig. 209; Van Heurck, *Traité des Diatomées*, 1899, p. 256, pl. 7, fig. 274; Schönfeldt, H., *Pascher's Süßwasser-Flora*, Heft 10, 1913, p. 117, fig. 255; Gustav, L., *Die Algen*, 1914, p. 165, pl. 12, fig. 320; Hustedt, Fr., *Pascher's Süßwasser-Flora*, Heft 10, 1930, p. 222, fig. 329; Skvortzow, B. W., *Diatoms from Poyang Lake, Hunan, China*, *Phil. Jour. Sci.*, Vol. 57, 1935, p. 468, pl. 2, fig. 1; *Diatoms from Kizaki Lake, Honshu Island, Nippon*, Vol. 61, 1936, p. 28, pl. 9, fig. 14; *Diatoms from Argun River, Hsing-An Pei Province, Manchauko*, Vol. 66, 1938, p. 49, pl. 1, fig. 7; Abdul-Majeed, M., *Fresh-water Algæ of the Panjab, Pt. I, Bacillariophyta (Diatomeæ)*, *Panjab University Publications*, Lahore, 1935, p. 20, pl. 3, fig. 7.

Frustules solitary. Valves sigmoid, lanceolate in outline, gradually tapering from the middle towards the ends which are broadly rounded. Raphe sigmoid, lying in the centre. Transverse and longitudinal striæ at equal distances from one another. Axial area very narrow, central area small and elliptical.

Dimensions .. Length 117-120  $\mu$

Breadth 15-16  $\mu$

Striæ 18 in 10  $\mu$

Habitat .. Fresh-water. Streams at Borivli; Powai Lake.  
Common.



63. *Gyrosigma attenuatum* (Kütz.) Rabh.

(Fig. 63)

Smith, W., *Syn. Brit. Diat.*, Vol. I, 1853, p. 68, pl. 22, fig. 216; Van Heurck, *Traité des Diatomées*, 1899, p. 255, pl. 7, fig. 271; Migula, W., *Kryptogamen-Flora*, Bd. II, Teil 1 a, 1907-09, p. 239, Taf. 9, fig. 2; Schönfeldt, H., Pascher's *Süsswasser-Flora*, Heft 10, 1913, p. 116, fig. 256; Hustedt, Fr. Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 224, fig. 330.

Valves narrowly sigmoid, lanceolate, gradually narrowed from the middle towards the poles which are obtusely rounded. Raphe central and sigmoid. Axial area narrow, central area small and elliptical. Transverse striæ more numerous and finer than the longitudinal ones, perpendicular to the middle line.

Dimensions .. Length 185-195  $\mu$   
 Breadth 23-25  $\mu$   
 Trans. striæ 16 in 10  $\mu$   
 Longit. striæ 12 in 10  $\mu$

Habitat .. Fresh-water. Pools at Wadala. Rare.

64. *Gyrosigma balticum* (Ehr.) Rabh.

(Fig. 64)

Van Heurck, *Traité des Diatomées*, 1899, p. 255, pl. 7, fig. 272; Migula, W., *Kryptogamen-Flora*, Bd. II, Teil 1 a, 1907-09, p. 240, pl. 9, fig. 1; Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 224, fig. 331; Carter, N., A comparative study of two salt marshes, Part II, *Jour. Ecol.*, Vol. 21, 1933, p. 193, fig. 21, 1-2; Venkataraman, G., A Systematic Account of Some South Indian Diatoms, *Proc. Ind. Acad. Sci.*, Vol. X, No. 6, Sect. B, 1939, p. 318, figs. 71, 72; Subrahmanyam, R., A Systematic Account of the Marine Plankton Diatoms of the Madras Coast, *Proc. Ind. Acad. Sci.*, Vol. 24, No. 4, Sect. B, 1946, p. 173, figs. 373-375.

Valves slightly sigmoid, linear, with more or less parallel sides. Poles broad, oblique and bluntly rounded. Raphe eccentric and sigmoid. Central area small. Transverse and longitudinal striæ equidistant.

Dimensions .. Length 207-225  $\mu$   
 Breadth 21-23.4  $\mu$   
 Striæ 16 in 10  $\mu$

Habitat .. Brackish-water. Chembur creek. Very common.

65. *Gryosigma kützingii* (Grun.) Cleve

(Fig. 65)

Schönfeldt, Pascher's *Süsswasser-Flora*, Heft 10, 1913, p. 117, fig. 257; Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 224, fig. 333; Skvortzow, B. W., Diatoms from Kizaki Lake, Honshu

Island, Nippon, *Phil. Jour. Sci.*, Vol. 61, 1936, p. 28, pl. 3, fig. 7; Diatoms from Ikeda Lake, Satsuma Province, Kiewisien Island, Nippon, Vol. 62, 1937, p. 197, pl. 1, fig. 4.

Valves slightly sigmoid, lanceolate with rounded ends. Raphe central and slightly sigmoid. Axial area narrow and linear, central area small. Transverse striæ coarse, longitudinal striæ fine and more in number than the transverse ones. Transverse striæ perpendicular to the middle line except in the centre where they are radial.

Dimensions .. Length 103–113  $\mu$   
 Breadth 14–16.3  $\mu$   
 Transverse striæ 20 in 10  $\mu$   
 Longitudinal striæ 24–26 in 10  $\mu$

Habitat .. Fresh-water. Streams at Borivli; Powai Lake.  
 Not common.

#### 66. *Gyrosigma scalproides* (Rabh.) Cleve

(Fig. 66)

Van Heurck, *Traité des Diatomées*, 1899, p. 259, pl. 7, fig. 284; Migula, W., *Kryptogamen-Flora*, Bd. II, Teil 1 a, 1907–09, p. 240, Taf. 9, fig. 5; Schönfeldt, Pascher's *Süßwasser-Flora*, Heft 10, 1913, p. 117, fig. 259; Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 226, fig. 338; Gustav, L., *Die Algen*, 1914, p. 165, pl. 12, fig. 322; Abdul-Majeed, M., Fresh-water Algæ of the Panjab, Pt. I, Bacillariophyta (Diatomeæ), *Panjab University Publications*, Lahore, 1935, p. 20, pl. 3, fig. 7; Skvortzow, B. W., Diatoms from Kizaki Lake, Honshu Island, Nippon, *Phil. Jour. Sci.*, Vol. 61, 1936, p. 28, pl. 12, fig. 5; Hustedt, Fr., Systematisch und Ökologisch untersuchung über die Diatomeen-Flora von Java, Bali und Sumatra nach dem Material Deutschen Limnologischen Expedition, Systematischer Teil, *Archiv für Hydrobiol.*, Suppl. Bd. XV, 1938, p. 188, pl. 14, fig. 3.

Valves slightly sigmoid, linear and slightly attenuated towards the ends which are obliquely rounded. Raphe central and sigmoid. Central area very small and narrow. Striæ fine, but distinct. Transverse striæ very slightly radial in the middle and perpendicular to the middle line throughout.

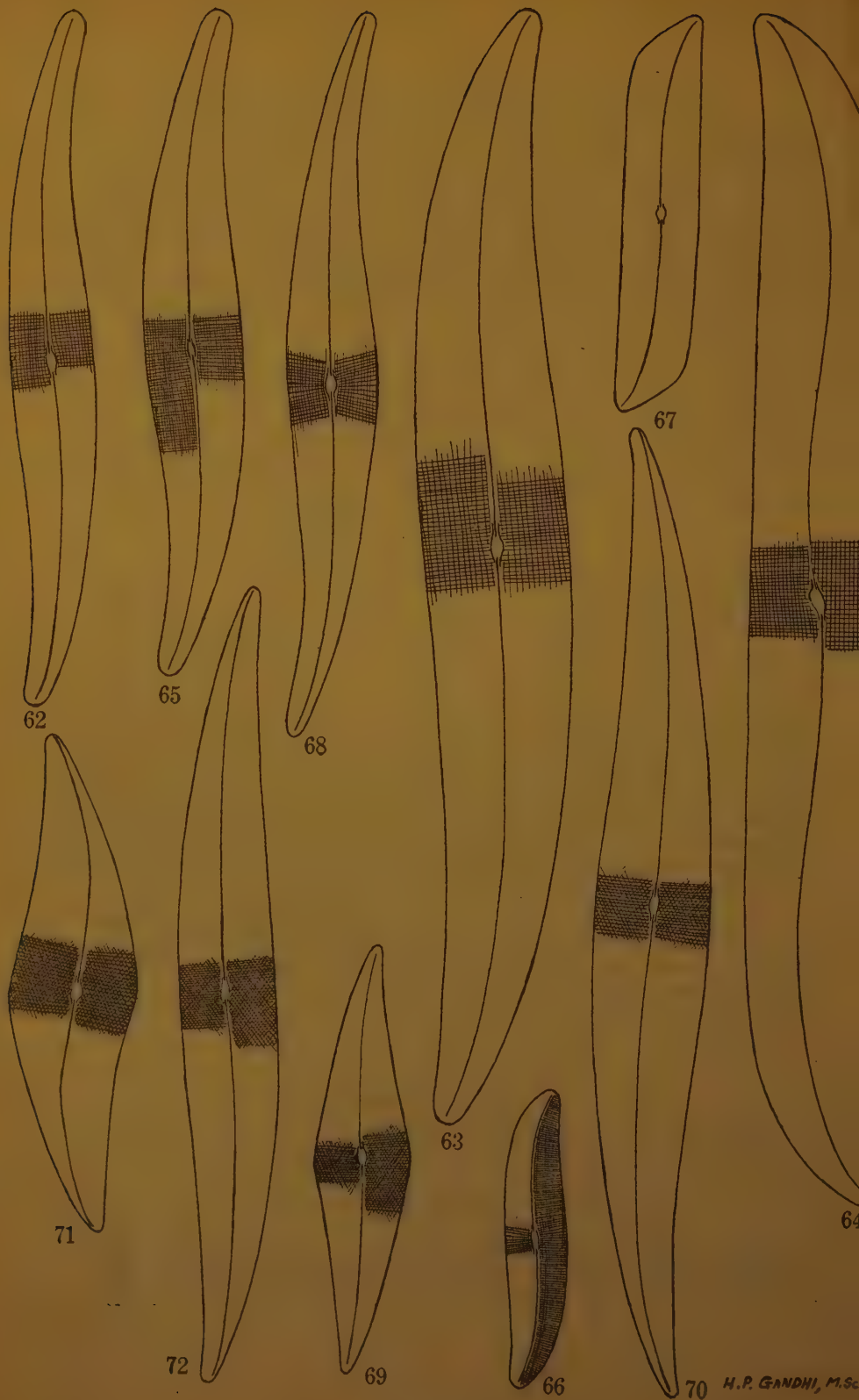
Dimensions .. Length 53–57  $\mu$   
 Breadth 10  $\mu$   
 Transverse striæ 24 in 10  $\mu$   
 Longitudinal striæ 26–28 in 10  $\mu$

Habitat .. Fresh-water. Pools at Wadala. Not common.

#### 67. *Gyrosigma scalproides* (Rabh.) Cleve var. *eximia* (Thw.) Cleve

(Fig. 67)

Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 226, fig. 339; Carter, N., A comparative study of two salt marshes, Pt. II,



H.P. GANDHI, M.Sc.

FIGS. 62-72

FIGS. 62–72. Fig. 62. *Gyrosigma acuminatum* (Kütz.) Rabh.,  $\times 840$ . Fig. 63. *Gyrosigma attenuatum* (Kütz.) Rabh.,  $\times 840$ . Fig. 64. *Gyrosigma balticum* (Ehr.) Rabh.,  $\times 840$ . Fig. 65. *Gyrosigma kützingii* (Grun.) Cleve,  $\times 840$ . Fig. 66. *Gyrosigma scalpoides* (Rabh.) Cleve,  $\times 840$ . Fig. 67. *Gyrosigma scalpoides* (Rabh.) Cleve var. *eximia* (Thw.) Cleve,  $\times 840$ . Fig. 68. *Gyrosigma baikalensis* Skv.,  $\times 840$ . Fig. 69. *Pleurosigma angulatum* (Quekett) W. Smith f. *chemburiana* forma nova.,  $\times 840$ . Fig. 70. *Pleurosigma elongatum* W. Smith,  $\times 840$ . Fig. 71. *Pleurosigma æstuari* Brebisson,  $\times 840$ . Fig. 72. *Pleurosigma delicatulum* W. Smith,  $\times 840$ .

*Jour. Ecol.*, Vol. 21, 1933, p. 193, fig. 18; Venkataraman, G., A Systematic Account of Some South Indian Diatoms, *Proc. Indian Acad. Sci.*, Vol. 10, Sect. B, 1939, p. 319, fig. 76.

Valves linear with parallel sides and obliquely rounded ends. Raphe straight, nearly central and slightly sigmoid at the poles. Striæ finely punctate; longitudinal striæ faint.

Dimensions .. Length 59.4–72  $\mu$   
 Breadth 12.6–14  $\mu$   
 Transverse striæ 25 in 10  $\mu$   
 Longitudinal striæ 30–32 in 10  $\mu$

Habitat .. Brackish-water. Mahim and Chembur creeks.  
 Common.

#### 68. *Gyrosigma baikalensis* Skv.

(Fig. 68)

Skvortzow, B. W., Bottom Diatoms from Olhon Gate of Baikal Lake, Siberia, *Phil. Jour. Sci.*, Vol. 62, 1937, p. 315, pl. 5, figs. 64–65.

Valves lanceolate-sigmoid. Ends produced and acutely rounded. Raphe sigmoid and central. Central area flexuose, small. Transverse striæ slightly radial in the middle and equal in number to the longitudinal striæ.

Dimensions .. Length 126–132  $\mu$   
 Breadth 15  $\mu$   
 Striæ 17–18 in 10  $\mu$

Habitat .. Fresh-water. Streams at Borivli. Rare.

#### Genus *Pleurosigma* W. Smith, 1852

#### 69. *Pleurosigma angulatum* (Quekett) W. Smith f. *chemburiana* forma nova

(Fig. 69)

Frustula libere natantia, solitaria, pallide brunneis pigmentis colorata. Valvæ tenuiter sigmoideæ, rhombico-lanceolatæ atque in medio distincte angulatæ. Apices acute rotundati. Raphe tenuiter sigmoidea atque tenuis. Area axialis angusta, area vero centralis parva atque rhombica. Striæ transverse atque oblique positæ, equidistantes ab alterutra.



Frustula 72–96  $\mu$  longa, 15–16.6 lata; striæ 20–24 in 10  $\mu$ .

Frustules free-floating, solitary with pale brown pigment. Valves slightly sigmoid, rhombic-lanceolate, distinctly angular in the middle. Ends acutely rounded. Raphe sigmoid and thin. Axial area narrow, central area small and rhombic. Transverse and obliquely placed striæ equidistant from one another.

Dimensions .. Length 72–96  $\mu$   
 Breadth 15–16.6  $\mu$   
 Striæ 20–24 in 10  $\mu$

Habitat .. Fresh-water. Pools at Wadala. Very common in brackish-waters of Mahim and Chembur creeks.

This fresh-water form is proportionately smaller than the type. The striæ are also finer and more closely placed. Hence it is regarded as a new form.

#### 70. *Pleurosigma elongatum* W. Smith

(Fig. 70)

Smith, W., *Syn. Brit. Diat.*, Vol. I, 1853, p. 64, pl. 20, fig. 199; Van Heurck, *Traité des Diatomées*, 1899, p. 253, pl. 6, fig. 262; Migula, W., *Kryptogamen Flora*, Bd. II, Teil 1 a, 1907–09, p. 237, Taf. 9 B, fig. 2; Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 228, fig. 343; Subrahmanyam, R., A Systematic Account of the Marine Plankton Diatoms of the Madras Coast, *Proc. Indian Acad. Sci.*, Vol. 24, Sect. B, 1946, p. 175, figs. 380–382.

Valves slightly sigmoid, elongated, somewhat lanceolate, gradually attenuated from the middle towards the poles which are acutely rounded. Raphe central, slightly sigmoid. Transverse striæ finer than the oblique ones.

Dimensions .. Length 168–180  $\mu$   
 Breadth 18–20.4  $\mu$   
 Transverse striæ 18–20 in 10  $\mu$   
 Oblique striæ 16–18 in 10  $\mu$

Habitat .. Brackish-water. Chembur creek. Fairly common.

#### 71. *Pleurosigma salinarum* Grun.

(Fig. 74)

Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 228, fig. 344; Venkataraman, G., A Systematic Account of Some South Indian Diatoms, *Proc. Indian Acad. Sci.*, Vol. 10, Sect. B, 1939, p. 321, figs. 78, 79.

Valves linear-lanceolate, sharply rounded at the poles, sigmoid. Raphe central, sigmoid. Axial area very narrow, central area small, elliptical. Oblique striæ more than the transverse ones and very conspicuous.

- Dimensions .. Length 110–125  $\mu$   
 Breadth 15–18  $\mu$   
 Transverse striæ 25 in 10  $\mu$   
 Oblique striæ 28–34 in 10  $\mu$
- Habitat .. Brackish-water. Chembur and Mahim creeks.  
 Common.

72. *Pleurosigma Normanii* Ralfs.

(Fig. 73)

Subrahmanyam, R., A Systematic Account of the Marine Plankton Diatoms of the Madras Coast, *Proc. Indian Acad. Sci.*, Vol. 24, No. 4, Sect. B, 1946, p. 175, figs. 378, 379, 385 and 387; Allen and Cupp, Plank. Diat. Java Sea, *Ext. Ann. Jard. Bot. Buitenzorg*, Vol. XLIX, 1935, p. 157, fig. 106.

Valves broadly lanceolate, sigmoid, with slightly acute, rounded ends. Raphe sigmoid and central. Axial area narrow; central area small and elongated. Transverse striæ distinct and more numerous than the oblique striæ.

- Dimensions .. Length 162–168  $\mu$   
 Breadth 28  $\mu$   
 Transverse striæ 19–21 in 10  $\mu$   
 Oblique striæ 17–18 in 10  $\mu$
- Habitat .. Brackish-water. Mahim creek. Common.

73. *Pleurosigma æstuari* Bréb.

(Fig. 71)

Migula, W., *Kryptogamen-Flora*, Bd. II, Teil 1 a, 1907–09, p. 235, Taf. IX, fig. 10.

*Pleurosigma angulata*, var. *æstuari* Smith, W., *Syn. Brit. Diat.*, Vol. I; Van Heurck, *Traité des Diatomées*, 1899, p. 251, pl. 6, fig. 256.

Valves broadly lanceolate, sigmoid. Raphe more strongly sigmoid than the valves, eccentric, somewhat angular. Transverse and oblique striæ almost equidistant.

- Dimensions .. Length 90–95  $\mu$   
 Breadth 21  $\mu$   
 Transverse striæ 18–20 in 10  $\mu$   
 Oblique striæ 20–22 in 10  $\mu$
- Habitat .. Brackish-water. Mahim creek. Very rare.

The sigmoid and eccentric raphe distinguishes the form from *P. angulatum* (Quekett) W. Smith var. *quadratum* W. Sm. This form is slightly broader than the type.



FIGS. 73-91

FIGS. 73-91. Fig. 73. *Pleurosigma normanii* Ralfs,  $\times 840$ . Fig. 74. *Pleurosigma salinarum* Grun.,  $\times 840$ . Fig. 75. *Caloneis silicula* (Ehr.) Cleve var. *gibberula* (Kütz.) Grun.,  $\times 840$ . Fig. 76. *Caloneis silicula* (Ehr.) Cleve var. *truncatula* Grun. f. *boriviana* forma nova.,  $\times 840$ . Fig. 77. *Neidium bisulcatum* (Lagerst.) Cleve f. *undulata* O. Mull.,  $\times 840$ . Fig. 78. *Neidium affine* (Ehr.) Cleve var. *amphirhynchus* (Ehr.) Cleve f. *truncatula* forma nova.,  $\times 840$ . Fig. 79. *Neidium iridis* (Ehr.) Cleve,  $\times 840$ . Fig. 80. *Neidium iridis* (Ehr.) Cleve f. *ambigua* forma nova.  $\times 840$ . Fig. 81. *Neidium productum* (W. Smith) Cleve var. *bombayensis* var. nova.,  $\times 840$ . Fig. 82. *Neidium dubium* (Ehr.) Cleve,  $\times 840$ . Fig. 83. *Neidium oblique-striatum* A.S. var. *parallela* var. nova.,  $\times 840$ . Fig. 84. *Neidium indicum* spec. nova.,  $\times 840$ . Fig. 85. *Neidium indicum* f. *undulata* forma nova.,  $\times 840$ . Fig. 86. *Neidium indicum* var. *capitata* var. nova.,  $\times 840$ . Fig. 87. *Diploneis subovalis* Cleve,  $\times 840$ . Fig. 88. *Diploneis Smithii* (Bréb.) Cleve,  $\times 840$ . Fig. 89. *Diploneis pseudovalis* Hust.,  $\times 840$ . Fig. 90. *Anomæoneis spherophora* (Kütz.) Pfitzer var. *Guntheri* O. Mull. f. *rostrata* forma nova.,  $\times 840$ . Fig. 91. *Anomæoneis spherophora* (Kütz.) Pfitzer,  $\times 840$ .

#### 74. *Pleurosigma delicatulum* W. Smith

(Fig. 72)

Smith, W., *Syn. Brit. Diat.*, Vol. I, 1853, p. 65, pl. 20, fig. 205; Gustav, L., *Die Algen*, 1914, p. 165, pl. 22, fig. 324.

Valves elongated and lanceolate, narrow, slightly sigmoid, with acutely rounded ends. Raphe very slightly eccentric. Central area small, elliptical. Transverse striae equal in number to the oblique ones and equidistant from one another.

Dimensions .. Length 230-253  $\mu$   
 Breadth 28-33  $\mu$   
 Striae 21-23 in 10  $\mu$

Habitat .. Brackish-water. Mahim creek. Rare.

#### Genus *Caloneis* Cleve, 1894

75. *Caloneis silicula* (Ehr.) Cleve var. *gibberula* (Kütz.) Grun.

(Fig. 75)

Hustedt, Fr., *Pascher's Süßwasser-Flora*, Heft 10, 1930, p. 238, fig. 365.

Valves linear with triundulate margins, slightly gibbous in the middle and towards the poles. Ends wedge-shaped, slightly contracted and produced, rounded. Raphe straight, ends of the raphe in the central area bent unilaterally. Axial area broad, lanceolate; central area wide, reaching the walls, in rare cases not reaching the walls. Striae radial, crossed by a thin line near the margins.

Dimensions .. Length 31-40  $\mu$   
 Breadth 7.2-8  $\mu$   
 Striae 18-20 in 10  $\mu$

Habitat .. Fresh-water. Streams at Borivli; pools at Jogeswari. Common.



76. *Caloneis silicula* (Ehr.) Cleve var. *truncatula* Grun.  
*borivliana* forma nova.

(Fig. 76)

Frustula libere natantia, pallide brunneis pigmentis colorata. Valvæ lineares atque gibbosæ in medio. Apices late cuneati. Raphe tenuis atque recta. Area axialis late lanceolata, area vero centralis late stauroida. Striæ tenuiter radiales in medio, perpendiculares in lineam mediam ad apices. Striæ decussatæ linea distincta ad margines.

Frustula 45–47  $\mu$  longa, 9  $\mu$  lata; striæ 18–20 in 10  $\mu$ .

Frustules free-floating with light brown pigment. Valves linear and gibbous in the middle. Ends broadly wedge-shaped. Raphe thin and straight. Axial area broadly lanceolate, central area broadly stauroid. Striæ slightly radial in the middle and perpendicular to the middle line towards the ends. Striæ crossed by a distinct line near the margins.

Dimensions .. Length 45–47  $\mu$   
Breadth 9  $\mu$   
Striæ 18–20 in 10  $\mu$

Habitat .. Fresh-water. Streams at Borivli. Rare.

This form differs from the type (Hustedt, Fr., in Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 238, figs. 363, 364) as the ends are distinctly wedge-shaped and not rounded. The dilation in the central region is also more pronounced. Hence it is regarded as a new form.

#### Genus *Neidium* Pfitzer

77. *Neidium bisulcatum* (Lagerst.) Cleve f. *undulata* O. Müll.

(Fig. 77)

Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 242, fig. 375; Skvortzow, B. W., Diatoms from a peaty bog in Lianchiho River Valley, Eastern Siberia, *Phil. Jour. Sci.*, Vol. 66, 1938, p. 167, pl. 1, fig. 1.

Valves linear, slightly gibbous in the middle, with broadly rounded, wedge-shaped ends. Raphe thin and straight; ends of the raphe in the central area bent in opposite directions, terminal fissures distinctly bifurcated. Axial area narrow, central area elliptical. Striæ fine, distinctly punctate, mostly perpendicular to the middle line and convergent at the poles. Longitudinal furrows present near the margins, crossing the striæ.

Dimensions .. Length 53–58  $\mu$   
Breadth 7.2–8  $\mu$   
Striæ 26 in 10  $\mu$

Habitat .. Fresh-water. Powai Lake. Not common.

78. *Neidium affine* (Ehr.) Cleve var. *amphirhynchus* (Ehr.) Cleve  
f. *truncatula* forma nova.

(Fig. 78)

Valvæ lineares, marginibus fere parallelis, ad apices subito contractæ atque productæ in late truncatos polos. Raphe tenuis, recta, apicibus vero in aream centralem versis, incurvatisque in directiones oppositas, fissuris vero terminalibus anguste bifurcatis. Area axialis angusta, nonnihil dilatata polos inter et centrum. Area centralis parva atque rhomboidea. Striæ tenuiter sed clare punctatæ atque decussatæ sulco hyalino prope margines.

Frustula 41–50  $\mu$  longa, 10–10.8  $\mu$  lata; striæ 20–22 in 10  $\mu$ .

Valves linear with almost parallel margins, suddenly contracted towards the ends and produced into broadly truncate poles. Raphe thin, straight; ends of the raphe in the central area bent in opposite directions, terminal fissures narrowly bifurcated. Axial area narrow, somewhat expanded between the poles and the centre. Central area small and rhomboid. Striæ fine, but clearly punctate, crossed by a hyaline furrow near the margins.

Dimensions .. Length 41–50  $\mu$   
Breadth 10–10.8  $\mu$   
Striæ 20–22 in 10  $\mu$

Habitat .. Fresh-water. Powai Lake. Not common.

This form seems to approach *N. affine* var. *amphirhynchus* (Hustedt, Fr., in Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 243, fig. 377) in general appearance. The walls however, are parallel and the ends are shortly produced and pronouncedly truncate. The hyaline furrow interrupting the striæ near the margin is also very distinct. Hence it is regarded as a new form.

79. *Neidium iridis* (Ehr.) Cleve

(Fig. 79)

Van Heurck, *Traité des Diatomées*, 1899, p. 220, pl. 5, fig. 212; Hustedt, Fr., Pascher's *Süßwasser Flora*, Heft 10, 1930, p. 245, fig. 379; Skvortzow, B. W., *Diatoms from Khingan, North Manchuria, China*, *Phil. Jour. Sci.*, Vol. 35, 1928, p. 41, pl. 2, fig. 7.

Valves linear-lanceolate with distinctly convex margins and broadly rounded ends. Raphe flaccid in the middle; ends of the raphe in the central area bent in opposite directions, terminal fissures bifurcated. Axial area widened between the centre and the poles, central area obliquely elliptical. Striæ distinctly punctate, slightly radial in the middle and more or less perpendicular to the middle line towards the ends. Striæ crossed by several longitudinal furrows near the margins.

- Dimensions .. Length 75–80  $\mu$   
 Breadth 14–15.2  $\mu$   
 Striæ 18 in 10  $\mu$
- Habitat .. Fresh-water. Streams at Borivli; Powai Lake.  
 Common.

These forms are slightly narrower than the type.

80. *Neidium iridis* (Ehr.) Cleve f. *ambigua* forma nova.

(Fig. 80)

Valvæ lineares, lateribus fere parallelis, apicibus vero late rotundatis atque distincte cuneatis. Raphe tenuis atque recta, apicibus vero in aream centralem versis, incurvatisque in contrarias directiones, fissuris vero terminalibus distincte furcatis. Striæ distincte punctatæ, tenuiter radiales in medio, sed perpendiculares in mediam lineam ad apices. Striæ decussatæ sulco marginali.

Frustula 86–92  $\mu$  longa, 18–19  $\mu$  lata; striæ 16–17 in 10  $\mu$ .

Valves linear with almost parallel sides and broadly rounded and distinctly wedge-shaped ends. Raphe thin and straight; ends of the raphe in the central area bent in opposite directions, terminal fissures distinctly forked. Striæ distinctly punctate, slightly radial in the middle and perpendicular to the middle line towards the ends. Striæ crossed by a marginal furrow.

- Dimensions .. Length 86–92  $\mu$   
 Breadth 18–19  $\mu$   
 Striæ 16–17 in 10  $\mu$

Habitat .. Fresh-water. Streams at Borivli; Powai Lake.  
 Not common.

This form comes nearest to *N. iridis* (Ehr.) Cleve f. *vernalis* Reichelt (Hustedt, Fr., in Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 245, fig. 380). The ends however, of this form are distinctly wedge-shaped and not rounded. The central area too, is larger, while the striæ are lineate near the margin. Hence it is regarded as a new form of *N. iridis* (Ehr.) Cleve.

81. *Neidium productum* (W. Smith) Cleve var. *bombayensis* var. nova.

(Fig. 81)

Valvæ lineari-ellipticæ, lateribus tenuiter undulatis. Apices subito contracti, producti atque late rotundati. Raphe tenuis atque recta, apicibus vero in aream centralem versis, incurvatisque in directiones contrarias, fissuris vero terminalibus distincte bifurcatis. Area axialis lata, atque dilatata polos inter et centrum. Area centralis magna, transverse elliptica. Striæ tenuiter radiales, distinctæ punctatæ, decussatæque ad margines sulcis longitudinalibus.

Frustula 104–107  $\mu$  longa, 27  $\mu$  lata; striæ 19–21 in 10  $\mu$ .

Valves linear-elliptical with slightly undulate sides. Ends abruptly contracted, produced and broadly rounded. Raphe thin and straight; ends of the raphe in the central area strongly bent in opposite directions, terminal fissures distinctly bifurcated. Axial area wide, dilated between the centre and the poles. Central area large and transversely elliptical. Striæ slightly radial and distinctly punctate, crossed at the margins by longitudinal furrows.

Dimensions .. Length 104–107  $\mu$   
 Breadth 27  $\mu$   
 Striæ 19–21 in 10  $\mu$

Habitat .. Fresh-water. Streams at Borivli; Powai Lake and pools at Wadala. Not common.

This form in general characters resembles *N. productum* (W. Smith) Ch. (Hustedt, Fr., in Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 245, fig. 383). It is however a narrower form. Moreover the walls are abruptly contracted near the ends which are produced and broadly rounded. The striæ too are more closely placed than in the type. Hence it is regarded as a new variety of *Neidium productum* (W. Smith) Cleve.

## 82. *Neidium dubium* (Ehr.) Cleve

(Fig. 82)

Schönfeldt, H., Pascher's *Süsswasser-Flora*, Heft 10, 1913, p. 75, fig. 140; Gustav, L., *Die Algen*, 1914, p. 160, pl. 11, fig. 314; Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 246, fig. 384 a; Skvortzow, B. W., Bottom Diatoms from Olhon Gate of Baikal Lake, Siberia, *Phil. Jour. Sci.*, Vol. 62, 1937, p. 319, pl. 9, fig. 41.

Valves broadly linear with slightly convex margins which taper somewhat suddenly to form narrowly produced, rostrate or slightly capitate ends. Raphe thin and straight. Axial area, linear. Central area small, circular or broadly elliptical. Striæ very fine, but distinctly punctate and radial, crossed by two to three longitudinal furrows near the margins. Marginal part of the striæ lineate.

Dimensions .. Length 50·4–55  $\mu$   
 Breadth 19  $\mu$   
 Striæ 20–22 in 10  $\mu$

Habitat .. Fresh-water. Streams at Borivli; Pools at Jogeshwari. Common.

The dimensions of the forms recorded here are slightly more than those of the type.

## 83. *Neidium oblique-striatum* A.S. var. *parallella* var. nova.

(Fig. 83)

Frustula spumæ infixa, pallide brunneis pigmentis colorata. Valvæ late lineares, lateribus parallelis, apicibus vero acutis cuneatis rotundatis. Raphe tenuis et recta, apicibus vero in aream centralem tenuiter



incurvatis, fissuris vero terminalibus bifurcatis. Area axialis linearis, area vero centralis oblique rectangularis. Striæ fortiter obliquæ atque lineatæ, ad margines interruptæ sulco hyalino.

Frustula 38–44  $\mu$  longa, 11–12.6  $\mu$  lata; striæ 18–20 in 10  $\mu$ .

Frustules embedded in scum, with pale brown pigment. Valves broadly linear, with parallel sides and wedge-shaped, rounded ends. Raphe thin and straight; ends of the raphe in the central area slightly bent, terminal fissures bifurcated. Axial area linear, central area obliquely rectangular. Striæ strongly oblique and lineate, interrupted near the margins by a hyaline furrow

Dimensions .. Length 38–44  $\mu$

Breadth 11–12.6  $\mu$

Striæ 18–20 in 10  $\mu$

Habitat .. Fresh-water. Pond at Dahisar, and rain-water puddles at Mira Road. Common.

This form resembles *N. iridis* var. *amphigomphus* (Ehr.) van Heurck (Hustedt, Fr., in Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 245, fig. 382), in outline, but differs in dimensions and the nature of the striæ. It resembles *N. oblique-striatum* A.S. var. *rostrata* Skw. (Skvortzwo, B. W., *Phil. Jour. Sci.*, Vol. 61, 1936, p. 30, pl. 4, fig. 16) in the nature of the striæ, but differs in shape. This form moreover, is proportionately much longer than the last-mentioned type. The perfectly parallel side walls and the acutely rounded wedge-shaped ends are certainly distinctive. Hence it is regarded as a new variety of *N. oblique-striatum* A.S.

#### 84. *Neidium indicum* spec. nova.

(Fig. 84)

Frustula in limo luto, pallide luteis pigmentis colorata. Valvæ lineares, lateribus parallelis vel tenuiter convexis, quæ subito contrahuntur atque fastigantur in apices anguste productos, acute cuneatos. Raphe tenuis, filiformis, apicibus vero in aream centralem versis, incurvatisque in directiones contrarias, fissuris vero terminalibus bifurcatis. Area axialis angusta, nonnihil distenta centrum inter et polos. Area centralis magna atque rhomboidea. Striæ radiales, subtiles sed distincte punctatæ, lineatæ ad margines, ubi sulci longitudinales illas decussant.

Frustula 63–75.6  $\mu$  longa, 11–15  $\mu$  lata; striæ 24–26 in 10  $\mu$ .

Frustules in muddy slime, with pale yellow pigment. Valves linear, with parallel or slightly convex sides, which suddenly contract and taper into narrowly produced acutely wedge-shaped ends. Raphe thin, thread-like; ends of the raphe in the central area bent in opposite directions, terminal fissures bifurcated. Axial area narrow, somewhat distended between the middle and the poles. Central area large, rhomboid. Striæ radial, fine but distinctly punctate, lineate near the margins where longitudinal furrows cross them.

- Dimensions .. Length 63–75.6  $\mu$   
 Breadth 11–15  $\mu$   
 Striæ 24–26 in 10  $\mu$
- Habitat .. Fresh-water. Powai Lake. Common.

The outline of this form remotely resembles that of *N. productum* (W. Smith) Cl. (Hustedt, Fr., in Pacher's *Süsswasser-Flora*, Heft 10, 1930, p. 245, fig. 383) from which however, it differs in being narrower, in the side walls being almost straight and in the ends being definitely wedge-shaped and pointed. Its appearance is certainly quite distinctive and it is therefore regarded as a new species.

85. *Neidium indicum* f. *undulata* forma nova.

(Fig. 85)

Forma hæc nova multis in partibus ad speciem typicam accedit; differt vero in eo quod margines sunt distincte triundulati, atque area centralis est rotundata, haud vero angularis.

This form is identical with *Neidium indicum* except that the margins are distinctly triundulate and the central area is rounded and not angular.

- Dimensions .. Length 84–86  $\mu$   
 Breadth 15  $\mu$   
 Striæ 24–26 in 10  $\mu$
- Habitat .. Fresh-water. Powai Lake. Common.

86. *Neidium indicum* var. *capitata* var. nova.

(Fig. 86)

Valvæ lineari-ellipticæ atque subito contractæ ad polos ad efformandos apices capitatos cuneatosque. Area centralis parva, rotundata. Raphe crassa; cœtera ut in typô.

Frustula 86–88  $\mu$  longa, 23  $\mu$  lata; striæ 25 in 10  $\mu$ .

Valves linear-elliptical, suddenly contracted towards the poles to form capitate and wedge-shaped ends. Central area small, rounded. Raphe thick. Other details as in the type.

- Dimensions .. Length 86–88  $\mu$   
 Breadth 23  $\mu$   
 Striæ 25 in 10  $\mu$
- Habitat .. Fresh-water. Powai Lake. Not common.

This form is distinguished from the type by its ends which are distinctly capitate and wedge-shaped. The raphe too is flaccid in the middle and not thin. The margins are very slightly triundulate. Hence it is regarded as a new variety of *N. indicum*.

Genus *Diploneis* Ehrenberg, 184087. *Diploneis subovalis* Cleve

(Fig. 87 A and B)

Ostrup, E., Fresh-water Diatoms from Iceland, *Bot. Iceland*, Vol. 2, 1932, Pt. II, p. 918, pl. 1, fig. 10; Rich, F., Contributions to our knowledge of the fresh-water algæ of Africa. 12. Some diatoms from the Victoria Falls, *Trans. Roy. Soc. S. Africa*, Vol. 24, 1936, Pt. III, p. 211, Pl. 10, fig. 1; Skvortzow, B. W., Notes on the algal flora of New-Zealand. I. Fresh-water Diatoms from New Zealand, *Phil. Jour. Sci.*, Vol. 67, 1938, p. 171, fig. 1 d; Venkataraman, G., A Systematic Account of Some South Indian Diatoms, *Proc. Indian Acad. Sci.*, Vol. 10, 1939, p. 322, pl. XVII, figs. 3-4; fig. 74.

Valves broadly elliptical with rounded ends. Central nodule large and rounded. Furrows narrow, very closely following the central nodule and its horns. Costæ strong, alternating with double rows of alveoli. With low magnification, the costæ appear strong with pin-headed ends towards the raphe.

Dimensions ..	Length 27-38 $\mu$
	Breadth 18-21.6 $\mu$
	Costæ 8-10 in 10 $\mu$
	Rows of alveoli 16-18 in 10 $\mu$
Habitat ..	Fresh-water. Pools at Borivli. Rare.

88. *Diploneis Smithii* (Bréb.) Cleve

(Fig. 88 A and B)

Van Heurck, *Traité des Diatomées*, 1899, p. 197, pl. 4, fig. 151; Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 253, fig. 402; Carter, N., A comparative study of two salt marshes, *Jour. Ecol.*, Vol. 21, Pt. II, 1933, p. 179, fig. 16; Skvortzow, B. W., Marine littoral diatoms from the environs of Vladivostok, *Phil. Jour. Sci.*, Vol. 47, 1932, p. 141, pl. 5, fig. 14; Diatoms from the bottom of the sea of Japan, *Phil. Jour. Sci.*, Vol. 47, 1932, p. 273, pl. 2, fig. 8; Subrahmanyam, R., A Systematic Account of Marine Plankton Diatoms of Madras Coast, *Proc. Indian Acad. Sci.*, Vol. 24, Sect. B, 1946, p. 180, fig. 399.

Valves elliptical with broad, rounded ends and strongly convex sides. Central nodule fairly strongly developed, rounded-quadrate. Furrows lanceolate, narrowing towards the poles. Horns strongly formed. Costæ robust, radial, alternating with double rows of alveoli.

Dimensions ..	Length 27-30 $\mu$
	Breadth 16.2 $\mu$
	Costæ 9 in 10 $\mu$
	Rows of alveoli 18-20 in 10 $\mu$
Habitat ..	Brackish-water. Chembur creek. Common.

89. *Diploneis pseudovalis* Hust.

(Fig. 89)

Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 253, fig. 403.

Valves linear-elliptical with broadly rounded ends. Central nodule very large, slightly rounded or quadrate. Furrows very narrow, equally broad throughout. Horns, linear. Costæ strong, slightly radial alternating with double rows of fine alveoli.

Dimensions .. Length 16–18  $\mu$   
 Breadth 9–9.5  $\mu$   
 Costæ 12 in 10  $\mu$   
 Rows of alveoli 26–28 in 10  $\mu$

Habitat .. Fresh-water. Garden tank of the Institute of Science, Bombay. Common.

**Genus** *Stauroneis* Ehrenberg, 1843

90. *Stauroneis phænicenteron* Ehr.

(Fig. 104)

Smith, W., *Syn., Brit. Diat.*, Vol. I, 1853, p. 59, pl. 19, fig. 185; Van Heurck, *Traité des Diatomées*, 1899, p. 159, pl. 1, fig. 50; Migula, W., *Kryptogamen-Flora*, 1907–09, Bd. II, Teil 1 a, p. 270, pl. 6, fig. 10; Gustav, L., *Die Algen*, 1914, p. 173, pl. 13, fig. 389; Schönfeldt, Pascher's *Süsswasser-Flora*, Heft 10, 1913, p. 113, fig. 247; Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 255, fig. 404; Skvortzow, B. W., Diatoms of Kizaki Lake, Honshu Island, Nippon, *Phil. Jour. Sci.*, Vol. 61, 1936, p. 32, pl. 5, fig. 19; Iyengar, M. O. P. and Subrahmanyam, R., Fossil Diatoms from the Karewa Beds of Kashmir, *Proc. Nat. Acad. Sci. India*, Vol. 13, Pt. 4, 1943, p. 230, figs. 11, 14, 15.

Valves lanceolate with broadly rounded and slightly constricted ends. Raphe straight, somewhat broad. Axial area fairly wide, central area stauroid, widening slightly near the margins. Striæ fine, but distinctly punctate and radial.

Dimensions .. Length 104–150  $\mu$   
 Breadth 19–25  $\mu$   
 Striæ 15–18 in 10  $\mu$

Habitat .. Fresh-water. Streams and pools at Borivli; Powai Lake. Very common.

91. *Stauroneis phænicenteron* Ehr. var. *vulgaris* Dippel f. *intermedia* Dippel.

(Fig. 103)

Skvortzow, B. W., Diatoms from Khingan, North Manchuria, China, *Phil. Jour. Sci.*, Vol. 35, 1928, p. 44, pl. 2, fig. 28.



Valves lanceolate with obtusely rostrate, slightly produced, capitate ends. Raphe thick, with curved terminal fissures. Axial area broadly linear, central area stauroid, widening near the margins. Striæ distinctly punctate and fewer than in *Stauroneis phaniceron*.

Dimensions .. Length 135–150·4  $\mu$

Breadth 25·5–27  $\mu$

Striæ 12–13 in 10  $\mu$

Habitat .. Fresh-water. Pools at Borivli; Powai Lake.  
Rather rare.

92. *Stauroneis phaniceron* Ehr. f. *capitata* forma nova.

(Fig. 92)

Valvæ anguste lanceolatæ atque tenues, magnis apicibus rotundatis capitatis. Raphe crassa, poris centralibus magnis atque fissuris terminalibus ornata. Area axialis sat lata; area vero centralis stauroido, tenuiter dilatata ad latera. Striæ subtiles sed distincte punctatæ atque fortiter radiales.

Frustula 113·4–120  $\mu$  longa, 21·6  $\mu$  lata; striæ 18–20 in 10  $\mu$ .

Valves narrowly lanceolate and delicate, with large, rounded, capitate ends. Raphe thick, with bifurcated terminal fissures. Axial area fairly wide, central area stauroid, slightly dilated towards the sides. Striæ fine, but distinctly punctate and strongly radial.

Dimensions .. Length 113·4–120  $\mu$

Breadth 21·6  $\mu$

Striæ 18–20 in 10  $\mu$

Habitat .. Fresh-water. Powai Lake. Not common.

This form in appearance resembles *S. anceps* Ehr. f. *gracilis* (Ehr.) Cl. (Hustedt, Fr., Pascher's *Süßwasser-Flora*, 1930, p. 256, fig. 406), but differs with regard to the nature of the raphe, which is here fairly thick as in *S. phaniceron* Ehr. and not thin. The striæ too are distinctly punctate. It resembles *S. phaniceron* Ehr. in all respects except for the capitate ends. It is therefore regarded as a new form of *S. phaniceron* Ehr.

93. *Stauroneis anceps* Ehr.

(Fig. 93)

Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 256, fig. 405.

Valves elliptic-lanceolate with constricted subcapitate and broadly rounded ends. Raphe thin, thread-like, straight, with slightly curved, terminal fissures. Axial area very narrow, central area wide and stauroid, widening towards the sides. Striæ indistinctly punctate and strongly radial.

Dimensions .. Length 54–60  $\mu$   
 Breadth 14·4–15  $\mu$   
 Striæ 18 in 10  $\mu$

Habitat .. Fresh-water. Pond at Goregaon; pools near Dahisar and Mira Road.

This form differs slightly from the type as the ends of the valves are neither produced nor distinctly capitate, but are subcapitate. Another slight difference is that the striæ are more distantly placed.

94. *Stauroneis anceps* Ehr. f. *gracilis* (Ehr.) Cleve

(Fig. 94)

Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 256, fig. 406; Skvortzow, B. W., Diatoms from Poyang Lake, Hunan, China, *Phil. Jour. Sci.*, Vol. 57, 1935, p. 469, pl. 2, fig. 2; Diatoms from Kizaki Lake, Honshu Island, Nippon, Vol. 61, 1936, p. 32, pl. 5, fig. 20.

Valves lanceolate, gradually tapering from the middle towards the poles, which are capitate. Raphe thin and straight. Axial area narrow, central area linear, stauroid. Striæ very indistinctly punctate, strongly radial.

Dimensions .. Length 110–120  $\mu$   
 Breadth 18–19·8  $\mu$   
 Striæ 20–22 in 10  $\mu$

Habitat .. Fresh-water. Powai Lake. Common.

95. *Stauroneis anceps* Ehr. f. *linearis* (Ehr.) Cleve

(Fig. 95)

Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 256, fig. 407; Skvortzow, B. W., Diatoms from Kizaki Lake, Honshu Island, Nippon, *Phil. Jour. Sci.*, Vol. 61, 1936, p. 32, pl. 5, fig. 14.

Valves linear with somewhat parallel sides, suddenly constricted towards the ends which are capitate. Raphe thin, thread-like. Axial area narrow, central area stauroid, slightly broader near the sides. Striæ fine but distinct, strongly radial.

Dimensions .. Length 43–50  $\mu$   
 Breadth 12·6–13  $\mu$   
 Striæ 22 in 10  $\mu$

Habitat .. Fresh-water. Pools on Chembur Hills. Common.

96. *Stauroneis anceps* Ehr. var. *hyalina* Brun and Peragallo f. *producta* forma nova.

(Fig. 96)

Valvæ lanceolatæ, ornatæ longis, anguste productis apicibus, qui sunt rotundati. Raphe nonnihil lata atque tenuiter curvatis fissuris



Figs. 92-104

Figs. 92–104. Fig. 92. *Stauroneis phænicenteron* Ehr. f. *gracilis* forma nova.,  $\times 840$ . Fig. 93. *Stauroneis anceps* Ehr.,  $\times 840$ . Fig. 94. *Stauroneis anceps* Ehr. f. *gracilis* (Ehr.) Cleve,  $\times 840$ . Fig. 95. *Stauroneis anceps* Ehr. f. *linearis* Cleve,  $\times 840$ . Fig. 96. *Stauroneis anceps* Ehr. var. *hyalina* Brun & Peragallo f. *producta* forma nova.,  $\times 840$ . Fig. 97. *Stauroneis angulare* spec. nova.,  $\times 840$ . Fig. 98. *Stauroneis acuta* W. Smith,  $\times 506$ . Fig. 99. *Stauroneis acuta* W. Smith (small form),  $\times 840$ . Fig. 100. *Stauroneis acuta* W. Smith var. *tenuis* var. nova.,  $\times 840$ . Fig. 101. *Stauroneis obtusa* var. *chemburiana* var. nova.,  $\times 840$ . Fig. 102. *Stauroneis obtusa* Lagerst. f. *indica* forma nova.,  $\times 840$ . Fig. 103. *Stauroneis phænicenteron* Ehr. var. *vulgaris* Dippel f. *intermedia* Dippel,  $\times 840$ . Fig. 104. *Stauroneis phænicenteron* Ehr.,  $\times 840$ .

terminalibus prædita. Area axialis angusta, centralis vero linearis stauroidea, Striæ minute punctatæ atque radiales.

Frustula  $82.3\text{--}85\ \mu$  longa,  $14.4\ \mu$  lata; striæ 28 in  $10\ \mu$ .

Valves lanceolate with long, narrow, drawn-out ends which are rounded. Raphe somewhat broad with slightly curved terminal fissures. Axial area narrow, central area linear, stauroid. Striæ finely punctate, radial.

Dimensions .. Length  $82.3\text{--}85\ \mu$   
 Breadth  $14.4\ \mu$   
 Striæ 28 in  $10\ \mu$

Habitat .. Fresh-water. Pond at Goregaon, Powai Lake.  
 Not common.

This form is exactly like *S. anceps* Ehr. var. *hyalina* Brun and Peragallo (Hustedt, Fr., in Pascher's *Süßwasser-Flora*, 1930, p. 256, fig. 408) except that the ends are greatly produced and the raphe is broader. Hence it is regarded as a new form.

#### 97. *Stauroneis angulare* spec. nov.

(Fig. 97)

Frustula in spuma marginali stagnorum atque lacunarum, pallide brunneis pigmentis ornata. Valvæ elliptico-rhomboideæ, angulares in medio, abrupte angustatæ ad efformandos apices distinctos capitatos. Raphe tenuis et recta. Area axialis moderate lata; centralis vero stauroidea, tenuiter dilatata ad latera. Striæ minute punctatæ et radiales.

Frustula  $77\text{--}85\ \mu$  longa,  $21.6\text{--}23\ \mu$  lata; striæ 25 in  $10\ \mu$ .

Frustules occurring in the marginal scum of ponds and pools, with pale brown pigment. Valves elliptic-rhomboid, angular in the middle, abruptly narrowing to form distinctly capitate ends. Raphe thin and straight. Axial area moderately broad, central area stauroid, widening slightly near the sides. Striæ finely punctate, radial.

Dimensions .. Length  $77\text{--}85\ \mu$   
 Breadth  $21.6\text{--}23\ \mu$   
 Striæ 25 in  $10\ \mu$

Habitat .. Fresh-water. Pond and pools at Dahisar, Mira Road, Powai Lake. Not common.



The shape of this form is distinctive. The valves are angular in the middle and also towards the ends of the marginal walls from where they contract abruptly to form distinctly capitate poles. The striæ too are finely punctate. It somewhat resembles *S. anceps* Ehr. but is a much broader form. Hence it is regarded as a new species.

### Section *Pleurostauron* W. Smith

#### 98. *Stauroneis acuta* W. Smith

(Figs. 98, 99)

Smith, W., *Syn. Brit. Diat.*, Vol. I, 1853, p. 59, pl. 19, fig. 187; Van Heurck, *Traité des Diatomées*, 1899, p. 159, pl. 1, fig. 51; Migula, W., *Kryptogamen-Flora*, 1907-09, Bd. II, Teil 1 a, p. 271, pl. 6, fig. 11; Schönfeldt, H., *Pascher's Süswasser-Flora*, Heft 10, 1913, p. 115, fig. 251; Gustav, L., *Die Algen*, 1914, p. 173, pl. 13, fig. 390; Hustedt, Fr., *Pascher's Süswasser-Flora*, Heft 10, 1930, p. 259, fig. 415 a.

Frustules in girdle view united together to form ribbons. Valves rhombic-lanceolate, tumid in the middle and broadly rounded at the ends. Longitudinal septa well developed. Raphe straight and expanded with ends in the central area slightly bent unilaterally and terminal fissures slightly curved. Axial area broad in the centre, narrowing towards the poles. Central area stauroid, widening near the sides. Striæ strongly radial, fine but distinctly punctate.

Dimensions .. Length 167-180  $\mu$   
 Breadth 37-38  $\mu$   
 Striæ 13-15 in 10  $\mu$

Habitat .. Fresh-water. Pond at Goregaon, pools in Hills near Chembur. Very common.

Much smaller forms (Fig. 99) were sometimes found (Length 50-60  $\mu$ , Breadth 11-13  $\mu$ ).

#### 99. *Stauroneis acuta* W. Smith var. *tenuis* var. nova.

(Fig. 100)

Frustula ut plurimum parva, in limo marginali lacunarum, unita per valvarum facies in catenas breves. Valvæ rhombicæ, plurimum dilatatæ in medio et subito contractæ medium inter et polos, ad efformandos apices late rotundatos. Raphe crassa et recta, et fissuris terminalibus haud profundis ornata. Area axialis angusta; centralis vero magna, stauroidea, dilatata ad latera. Striæ radiales, indistincte punctatæ et proxime positæ.

Frustula 50-60  $\mu$  longa, 11-13  $\mu$  lata; striæ 20-22 in 10  $\mu$ .

Frustules usually small, occurring in the marginal slime of pools, united by their valve faces in short ribbons. Valves rhombic, very much dilated in the middle and suddenly contracted between the middle and poles to form produced, broadly rounded ends. Raphe

straight and thick, with shallow, terminal fissures. Axial area narrow, central area large, stauroid, widening near the sides. Striæ radial, slightly curved, indistinctly punctate, and very closely placed.

Dimensions .. Length 50–60  $\mu$   
 Breadth 11–13  $\mu$   
 Striæ 20–22 in 10  $\mu$

Habitat .. Fresh-water. Streams and pools on Chembur Hills. Not common.

This form resembles *S. acuta* W. Smith in general outline, being expanded in the middle and having broadly rounded ends. It is, however, small and slender and almost from the middle contracts sharply. It is also greatly produced towards the poles. The striæ too are slightly curved and more closely placed. Hence it is regarded as a new variety of *S. acuta* W. Smith.

100. *Stauroneis obtusa* Lagerst var. *chemburiana* var. nova.

(Fig. 101)

Frustula solitaria, libere natantia, occurrentia ut spuma marginalis brunnea in aquis stagnosis. Valvæ ellipticæ vel elliptico-lanceolatæ; apices late rotundati. Septa longitudinalia bene evoluta atque elliptica. Raphe latissima, angustata ad apices, fissuris terminalibus haud profundis ornata. Area axialis lata, lanceolata; centralis vero lata, stauroida. Striæ fortiter radiales atque distinctissime punctatæ.

Frustula 125–130  $\mu$  longa, 31–31.5  $\mu$  lata; striæ 12–13 in 10  $\mu$ .

Frustules solitary, free-floating, occurring in the brownish, marginal scum of streams. Valves elliptical or elliptical-lanceolate. Ends broadly rounded. Longitudinal septa strongly developed and elliptical. Raphe very broad, narrowing towards the ends, with shallow terminal fissures. Axial area wide, lanceolate. Central area wide, stauroid. Striæ strongly radial and very distinctly punctate.

Dimensions .. Length 125–130  $\mu$   
 Breadth 31–31.5  $\mu$   
 Striæ 12–13 in 10  $\mu$

Habitat .. Fresh-water. Streams at Chembur. Rare.

This form belongs to the section Pleurostauron, because of the longitudinal septa. It differs from *Stauroneis obtusa* Lagerst (Hustedt, Fr., Pascher's *Süßwasser-Flora*, 1930, p. 259, fig. 416), as it is more robust and possesses broadly rounded poles. It also has a very broad raphe and no polar septa. Hence it is regarded as a new variety of *S. obtusa* Lagerst.

101. *Stauroneis obtusa* Lagerst. f. *indica* forma nova.

(Fig. 102)

Valvæ lanceolatæ, apicibus angustis rotundatis. Septa longitudinalia bene evoluta, septis polaribus nullis. Raphe recta, tenuiter

incrassata et fissuris terminalibus haud profundis ornata. Area axialis angusta, aliquantum linearis; centralis vero area linearis, stauroida. Striæ radiales et distincte punctatæ.

Frustula 75–80  $\mu$  longa, 14–15  $\mu$  lata; striæ 18–20 in 10  $\mu$ .

Valves lanceolate with narrow, rounded ends. Longitudinal septa well-developed, polar septa absent. Raphe straight, slightly thickened, with shallow terminal fissures. Axial area narrow, Central area linear and stauroid. Striæ radial and distinctly punctate.

Dimensions .. Length 75–80  $\mu$   
 Breadth 14–15  $\mu$   
 Striæ 18–20 in 10  $\mu$

Habitat .. Fresh-water. Streams and pools in hills near Chembur. Fairly common.

This form resembles *S. obtusa* Lag. (Hustedt, Fr., Pascher's *Süßwasser-Flora*, 1930, p. 259, fig. 416) except that the poles are narrowly rounded and the polar septa are absent.

### Genus *Anomæoneis* Pfitzer, 1871

#### 102. *Anomæoneis sphaerophora* (Kütz.) Pfitzer

(Fig. 91)

Schönfeldt, H., Pascher's *Süßwasser-Flora*, Heft 10, 1913, p. 87, fig. 174, Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 262, fig. 422; Fritsch, F. E., and Rich, F., Contribution to our knowledge of the fresh-water algæ of Africa. Bacillariales (Diatoms) from Griqualand, West, *Trans. Roy. Soc. S. Africa*, Vol. 18, 1930, p. 103, fig. 4 a; Abdul-Majeed, M., Fresh-water algæ of the Panjab, Pt. I. Bacillariophyta (Diatomeæ), *Panjab University Publications*, Lahore, 1935, p. 122, pl. III, fig. 9; Venkataraman, G., A Systematic Account of Some South Indian Diatoms, *Proc. Indian Acad. Sci.*, Vol. 10, Sect. B, 1939, p. 324, fig. 75.

Valves elliptical-lanceolate with rostrate, capitate ends. Raphe straight, with semi-circular terminal fissures. Axial area broad, linear. Central area large, asymmetrical. Striæ radial, clearly punctate and interrupted by blank spaces.

Dimensions .. Length 73–80  $\mu$   
 Breadth 21·6–22  $\mu$   
 Striæ 15–17 in 10  $\mu$   
 Punctæ 16–18 in 10  $\mu$

Habitat .. Fresh-water. Powai Lake; streams at Borivli and pond at Dahisar. Common.

The ends of this form are more constricted and more distinctly capitate than in the type.



103. *Anomæoneis sphærophora* (Kütz.) Pfitzer var. *Guntheri* (Ehr.)  
Mull. f. *rostrata* forma nova.

(Fig. 90)

Valvæ elliptico-lanceolatæ, apicibus tenuiter productis, late rotundatis, haud capitatis ornatae. Area axialis lata, linearis; centralis vero aliquantum asymmetrica, sed haud producta usque ad latera. Striæ radiales atque distincte punctatae, punctis vero interruptis per plurima vacua spatia longitudinalia.

Frustula 63–68  $\mu$  longa, 21–22  $\mu$  lata; striæ 15–17 in 10  $\mu$ ; punctæ 18–20 in 10  $\mu$ .

Valves elliptical-lanceolate with slightly produced, broadly-rostrate ends which are not capitate. Axial area wide. Central area somewhat asymmetrical, but not reaching the sides. Striæ radial and distinctly punctate, punctæ interrupted by blank spaces.

Dimensions .. Length 63–68  $\mu$   
Breadth 21–22  $\mu$   
Striæ 15–17 in 10  $\mu$   
Punctæ 18–20 in 10  $\mu$

Habitat .. Brackish-water at Mahim and pond at Dharavi.  
Abundant.

This form in outline seems to be between *A. sphærophora* var. *sculpta* (Ehr.) Mull (Hustedt, Fr., Pascher's *Süsswasser-Flora*, 1930, p. 262, fig. 423) and *A. sphærophora* var. *Guntheri* (Hustedt, *op. cit.*, p. 262, fig. 424). Its ends are not as produced as in var. *sculpta*, nor are they as broad as in var. *Guntheri*. As it resembles the latter variety more, it is regarded as a new form of this type.



## REVIEW

**Rice.** By D. H. GRIST. Published by Longmans, Green & Co., London. Available in India from Orient Longmans Ltd., Bombay, Calcutta & Madras, 1953. Price. 35 s.

Rice is the staple food of the great majority of the people of Asia and the most important single crop in the world today. It is also the crop which is in short supply and increase of rice production is the most important problem facing the agriculturists of the world today, especially in India. The only previous book on this crop by E. R. Copeland, was published more than thirty years ago and much of the matter included in it is out of date. From this view-point Grist's book meets an urgent demand.

The author, who writes from a long experience of rice cultivation in South-East Asia, has covered almost all aspects of rice production, such as irrigation, varieties, pests and diseases, methods of cultivation, fertilisers and manures, storage, milling and economics of the crop. The book is neatly printed and illustrated by numerous drawings and photographs, some of which are in colour. A few errors however, have crept in. For example, Fig. 4 would be better described as a spikelet or flower of rice rather than as "Inflorescence of rice". It can be hoped that such minor mistakes will be corrected in the next edition. Meanwhile, this book can be recommended as a very useful aid to all who are engaged in the cultivation of rice.

A. C. J.